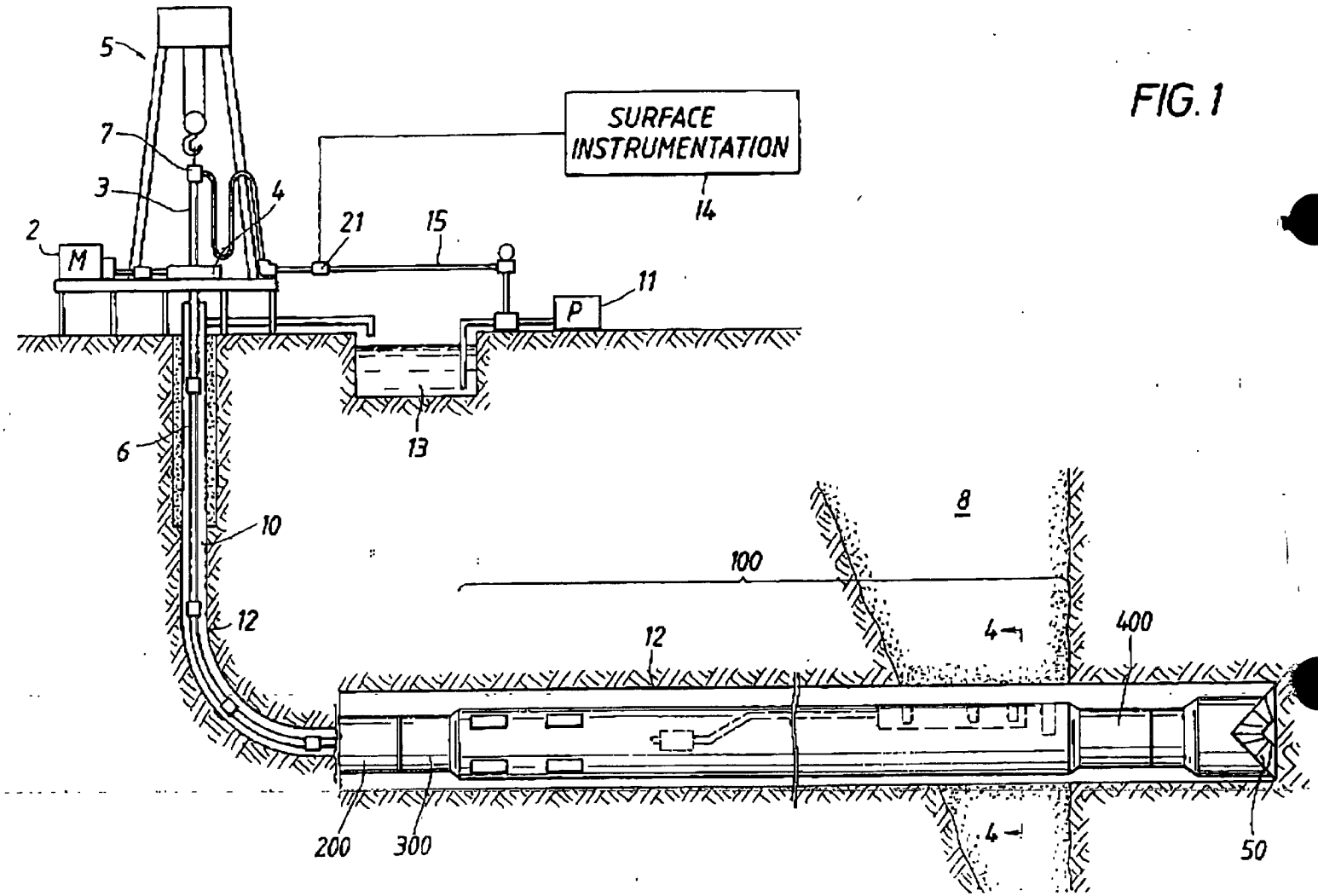

SURFACE
INSTRUMENTATION
14
5
7
3
4
2
M
21
15
11
P
13
6
10
12
8
100
12
4
400
4
200
300
50

FIG. 1

FIG.2

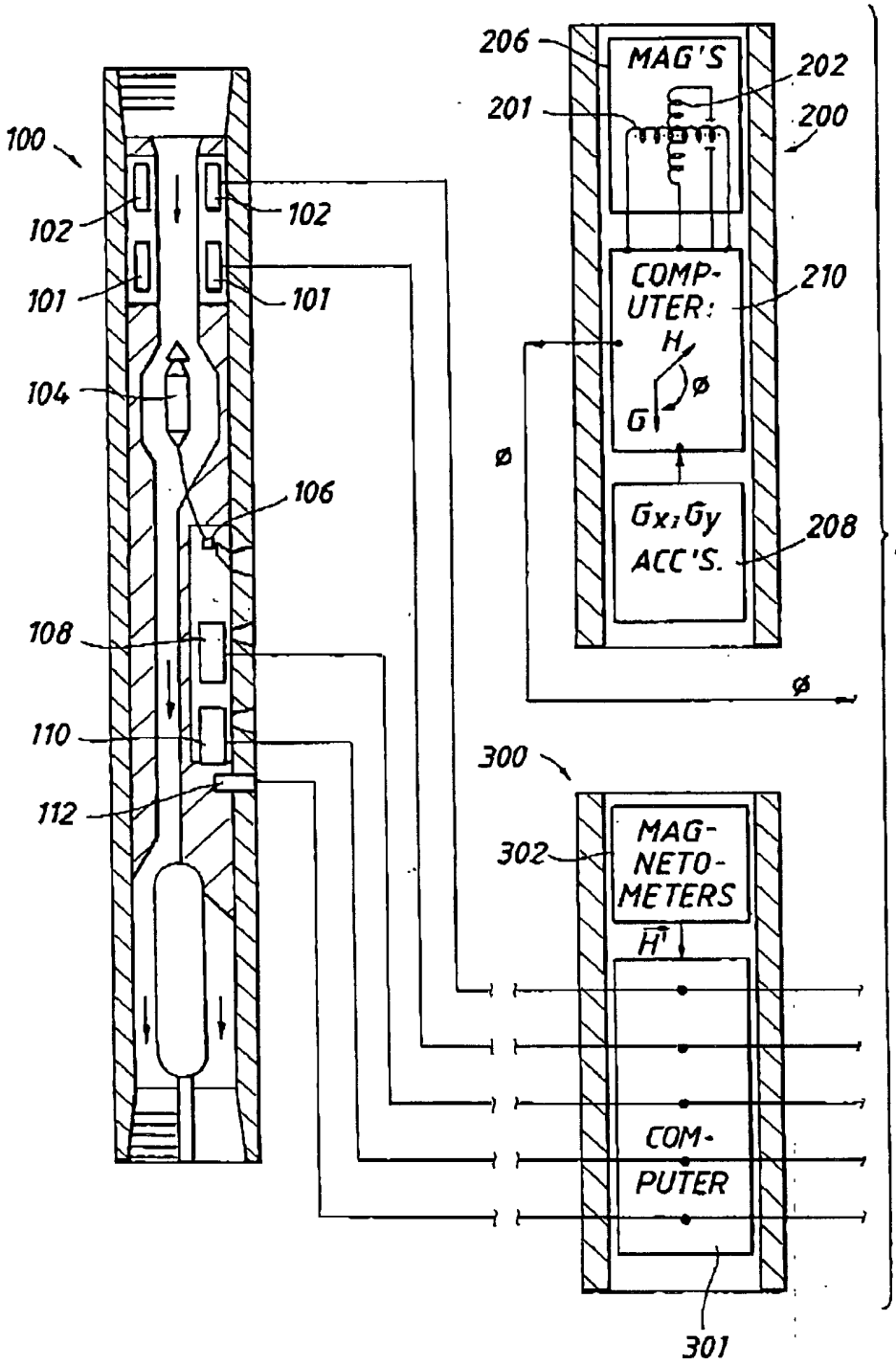

100
102
102
101
101
104
106
108
110
112
206
MAG'S
202
201
200
COMP-
UTER:
210
H
ø
G
ø
Gx;Gy
ACC'S.
208
ø
300
302
MAG-
NETO-
METERS
H
COM-
PUTER
301

FIG.3A

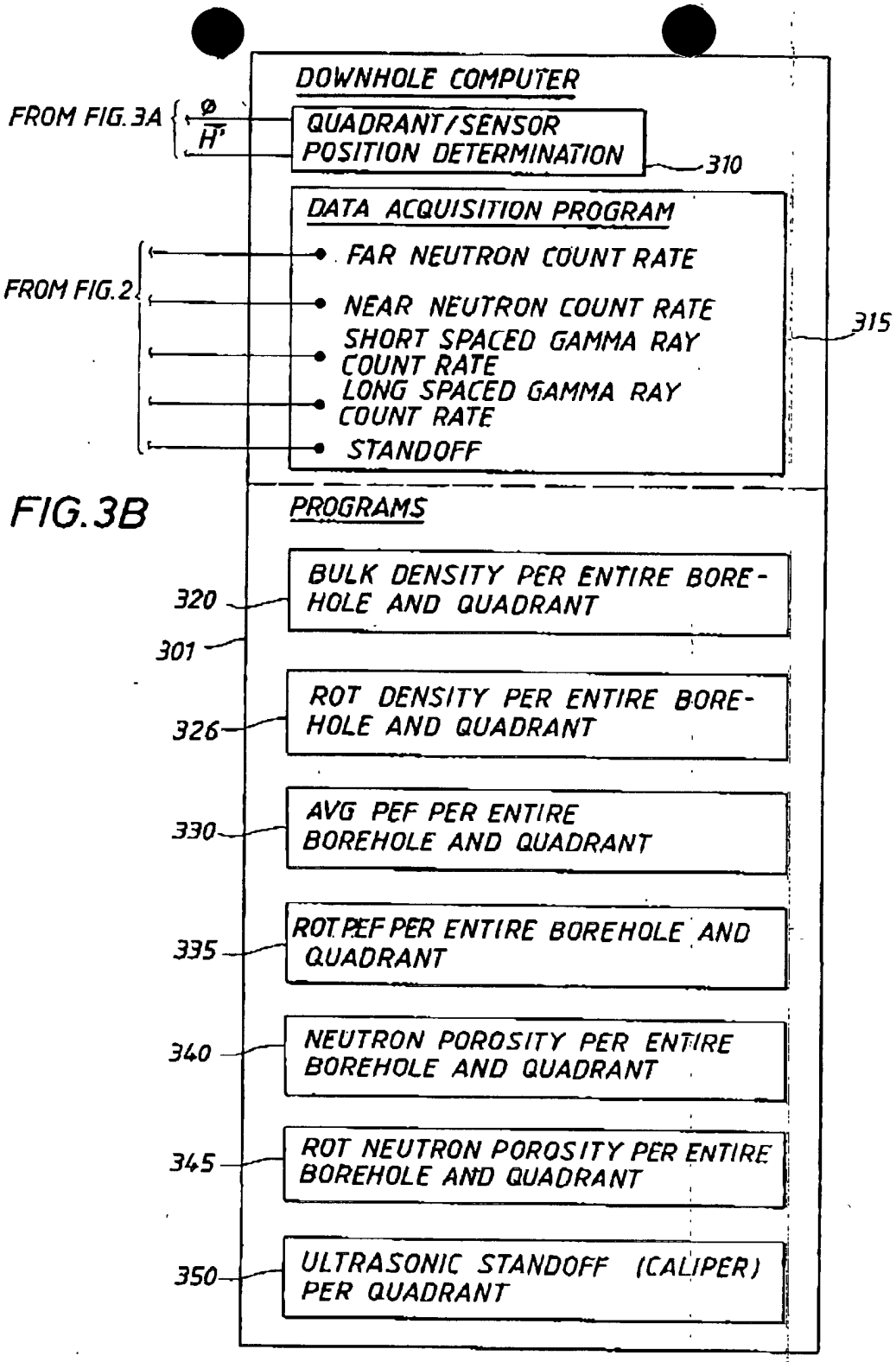

DOWNHOLE COMPUTER
FROM FIG. 3A
Ø
H'
QUADRANT/SENSOR POSITION DETERMINATION
310
DATA ACQUISITION PROGRAM
FROM FIG. 2
FAR NEUTRON COUNT RATE
NEAR NEUTRON COUNT RATE
SHORT SPACED GAMMA RAY COUNT RATE
LONG SPACED GAMMA RAY COUNT RATE
STANDOFF
315
PROGRAMS
320
BULK DENSITY PER ENTIRE BOREHOLE AND QUADRANT
301
326
ROT DENSITY PER ENTIRE BOREHOLE AND QUADRANT
330
AVG PEF PER ENTIRE BOREHOLE AND QUADRANT
335
ROT PEF PER ENTIRE BOREHOLE AND QUADRANT
340
NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT
345
ROT NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT
350
ULTRASONIC STANDOFF (CALIPER) PER QUADRANT

FIG. 3B

FIG. 4A

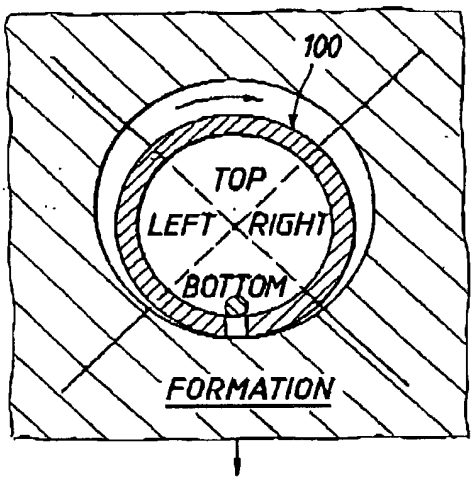
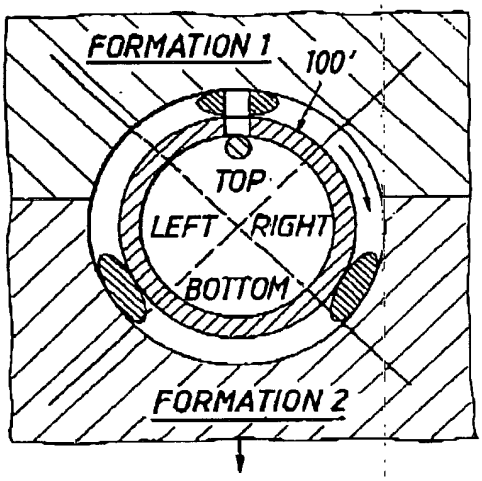


FIG. 4B



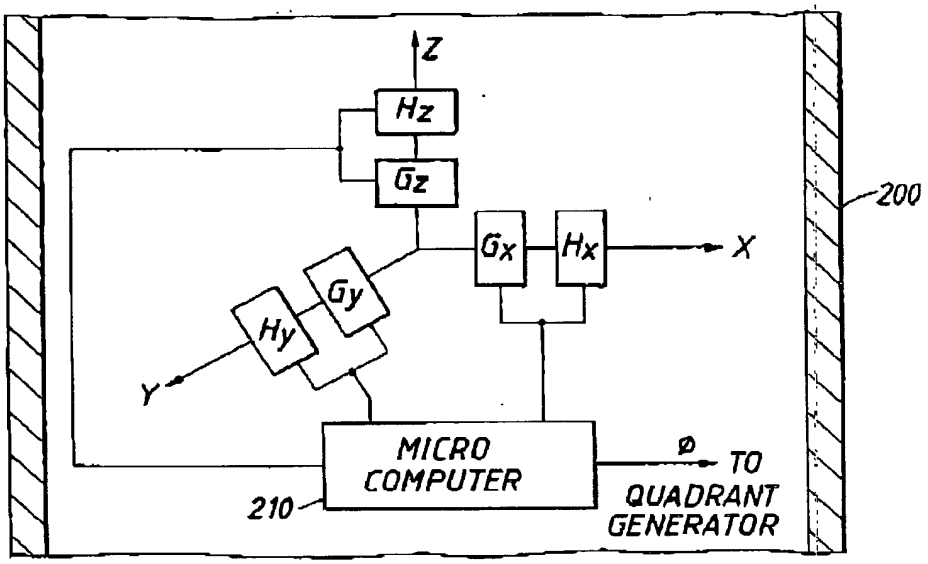


FIG. 5A

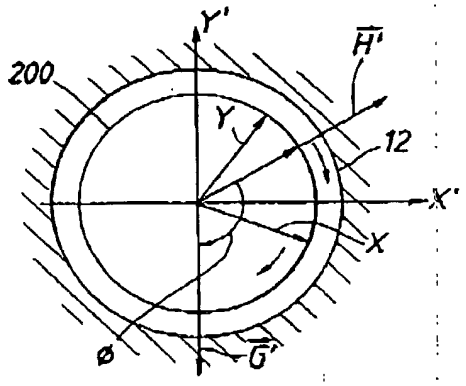


FIG. 5B

FIG. 6A

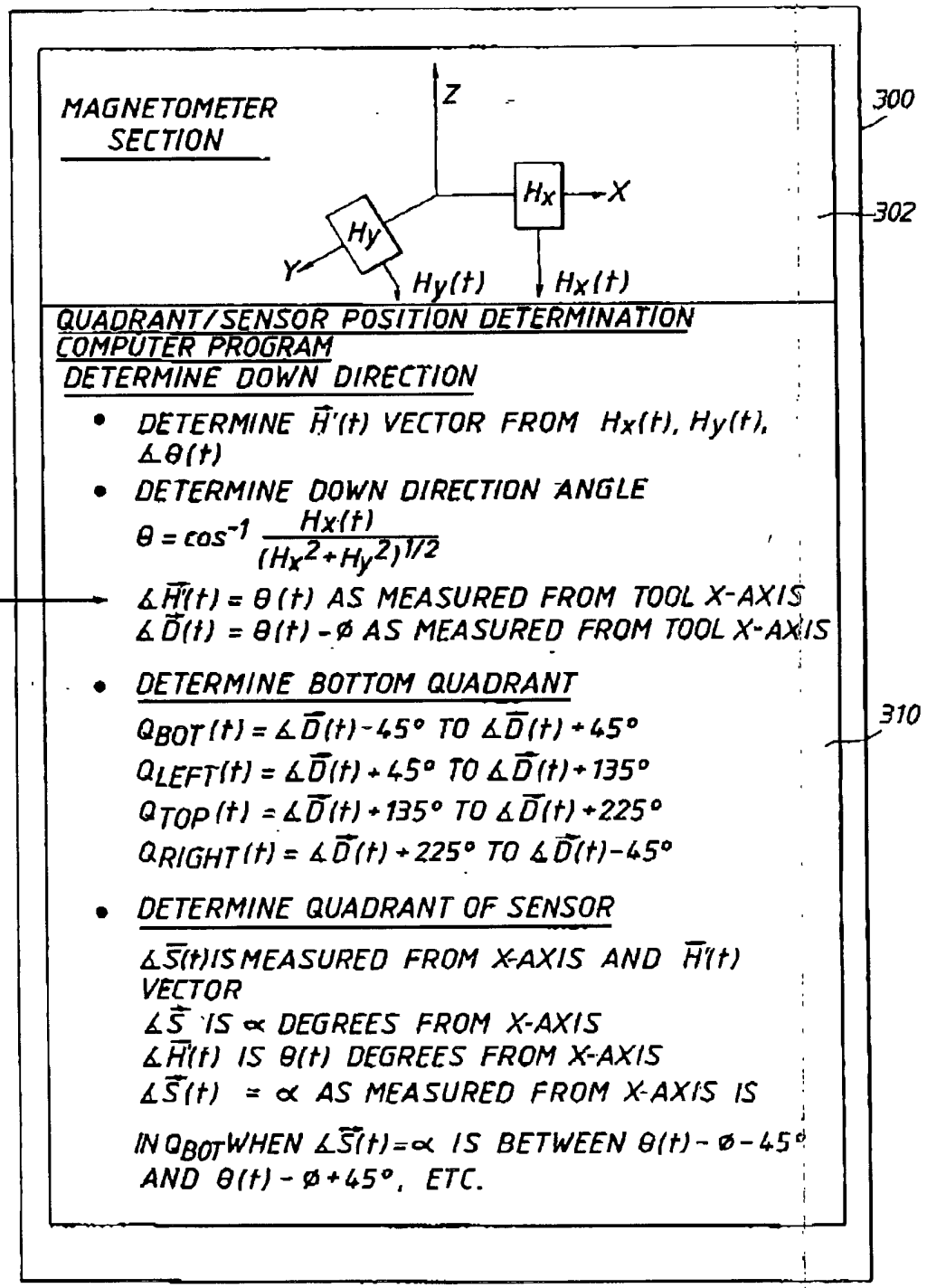

MAGNETOMETER SECTION
Z
Hx
X
Hy
Y
Hy(t)
Hx(t)
300
302
QUADRANT/SENSOR POSITION DETERMINATION COMPUTER PROGRAM
DETERMINE DOWN DIRECTION
• DETERMINE $\vec{H}'(t)$ VECTOR FROM Hx(t), Hy(t), $\angle\theta(t)$
• DETERMINE DOWN DIRECTION ANGLE
$\theta = \cos^{-1} \frac{Hx(t)}{(Hx^2+Hy^2)^{1/2}}$
ø
$\angle\vec{H}'(t) = \theta(t)$ AS MEASURED FROM TOOL X-AXIS
$\angle\vec{D}(t) = \theta(t) - ø$ AS MEASURED FROM TOOL X-AXIS
• DETERMINE BOTTOM QUADRANT
310
$Q_{BOT}(t) = \angle\vec{D}(t) - 45°$ TO $\angle\vec{D}(t) + 45°$
$Q_{LEFT}(t) = \angle\vec{D}(t) + 45°$ TO $\angle\vec{D}(t) + 135°$
$Q_{TOP}(t) = \angle\vec{D}(t) + 135°$ TO $\angle\vec{D}(t) + 225°$
$Q_{RIGHT}(t) = \angle\vec{D}(t) + 225°$ TO $\angle\vec{D}(t) - 45°$
• DETERMINE QUADRANT OF SENSOR
$\angle\vec{S}(t)$ IS MEASURED FROM X-AXIS AND $\vec{H}'(t)$ VECTOR
$\angle\vec{S}$ IS α DEGREES FROM X-AXIS
$\angle\vec{H}'(t)$ IS $\theta(t)$ DEGREES FROM X-AXIS
$\angle\vec{S}(t) = \alpha$ AS MEASURED FROM X-AXIS IS
IN Q_{BOT} WHEN $\angle\vec{S}(t) = \alpha$ IS BETWEEN $\theta(t) - ø - 45°$ AND $\theta(t) - ø + 45°$, ETC.

FIG.6B

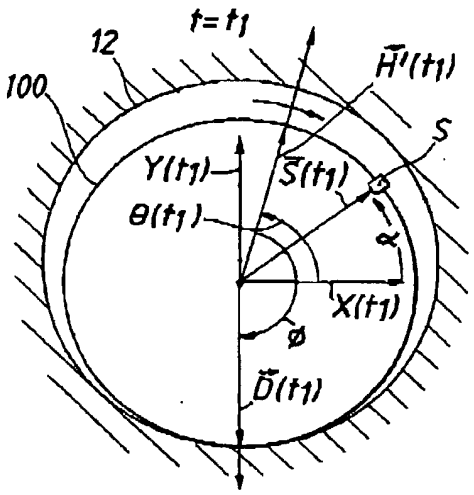
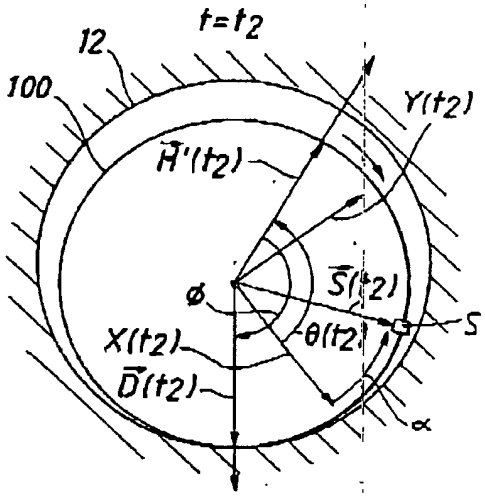


FIG.6C



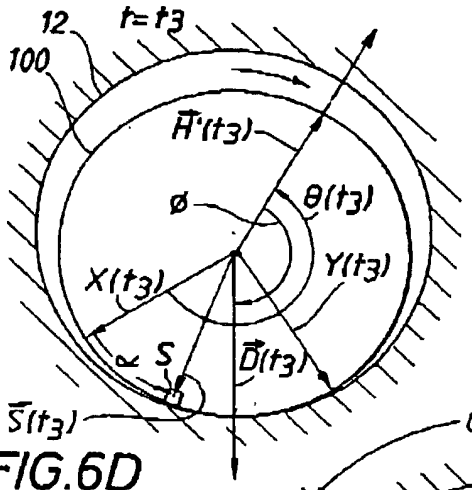


FIG.6D

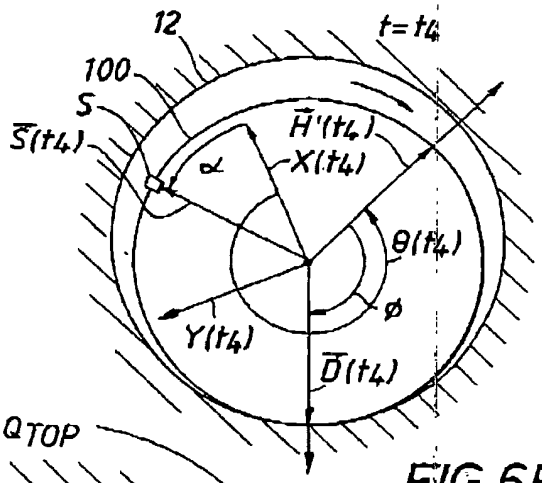


FIG.6E

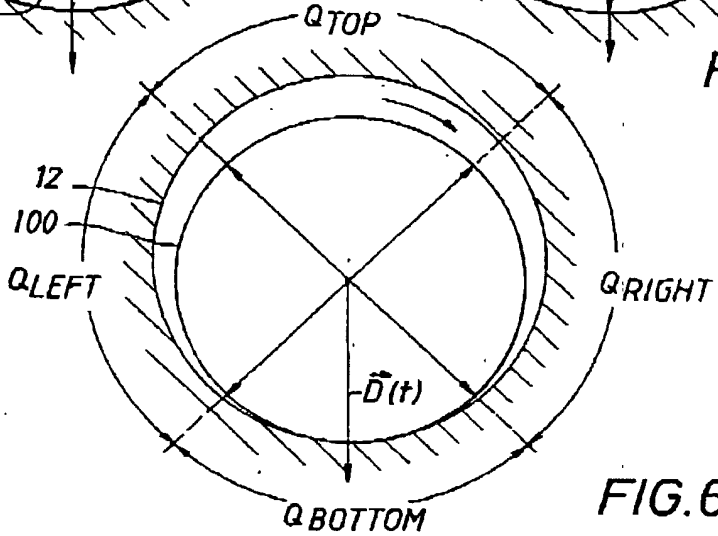


FIG.6F

FIG. 7A

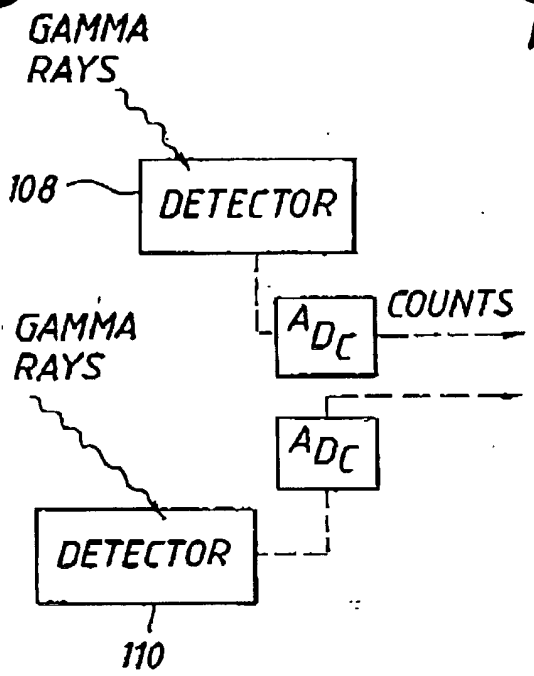

GAMMA RAYS
108
DETECTOR
COUNTS
GAMMA RAYS
DETECTOR
110

FIG. 7B

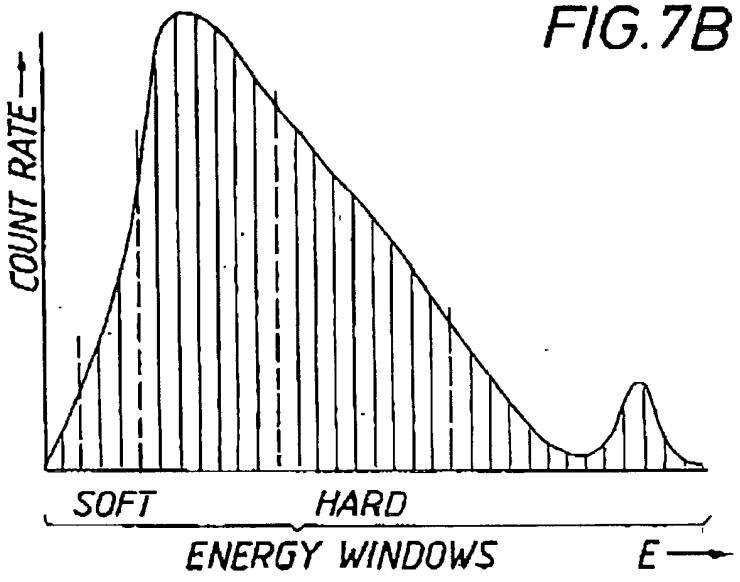

COUNT RATE
SOFT
HARD
ENERGY WINDOWS
E

FIG. 8

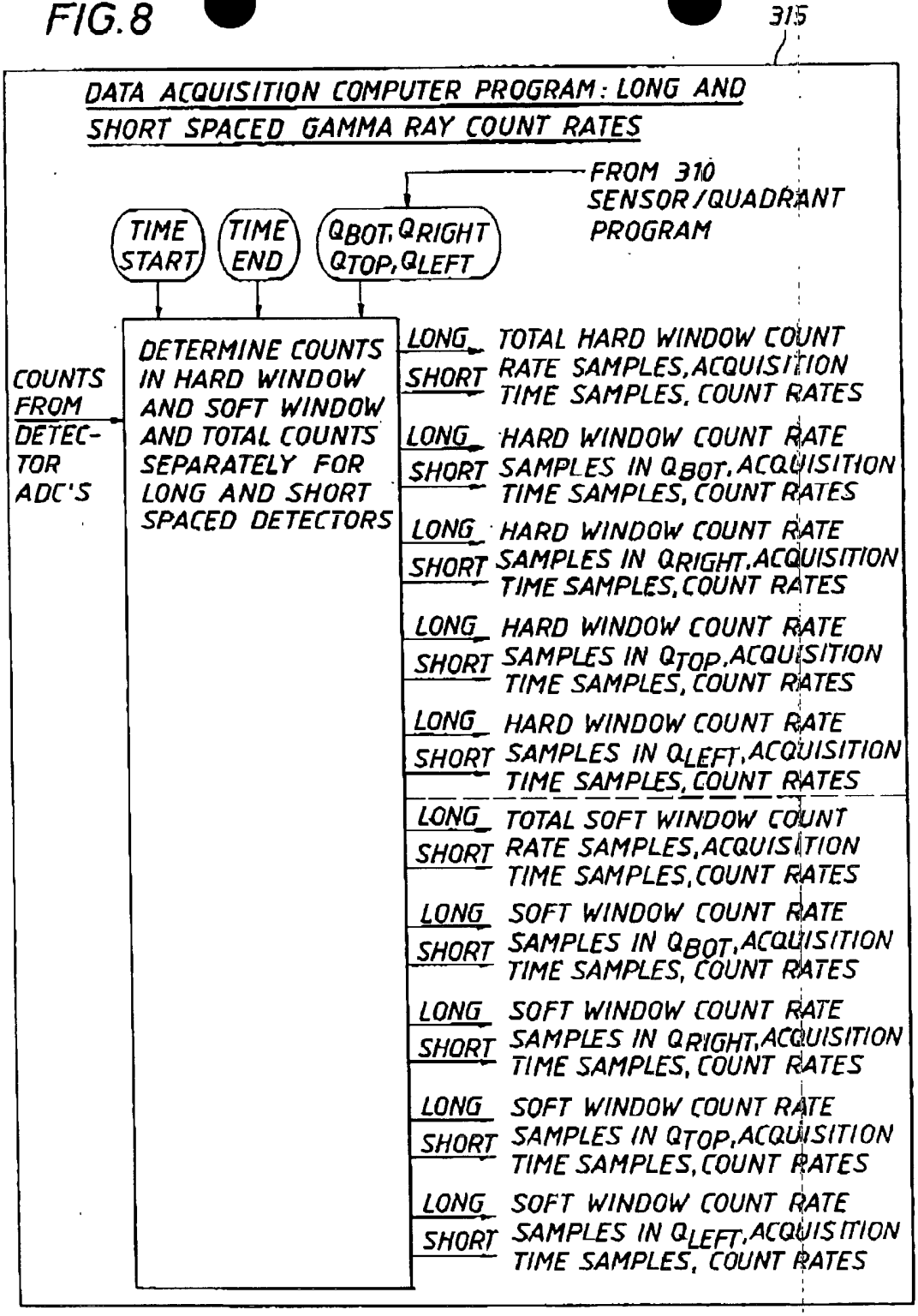


FIG.9

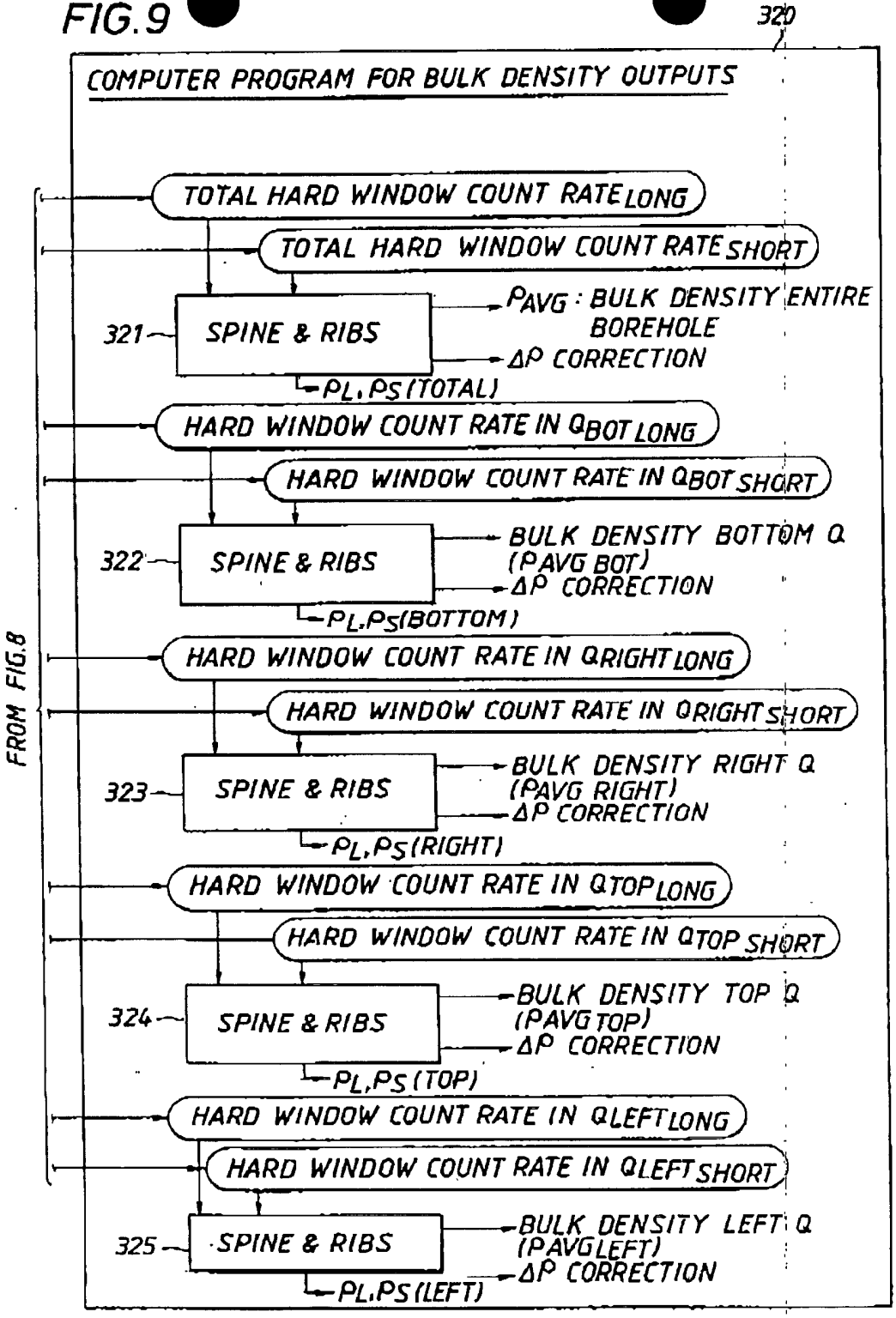
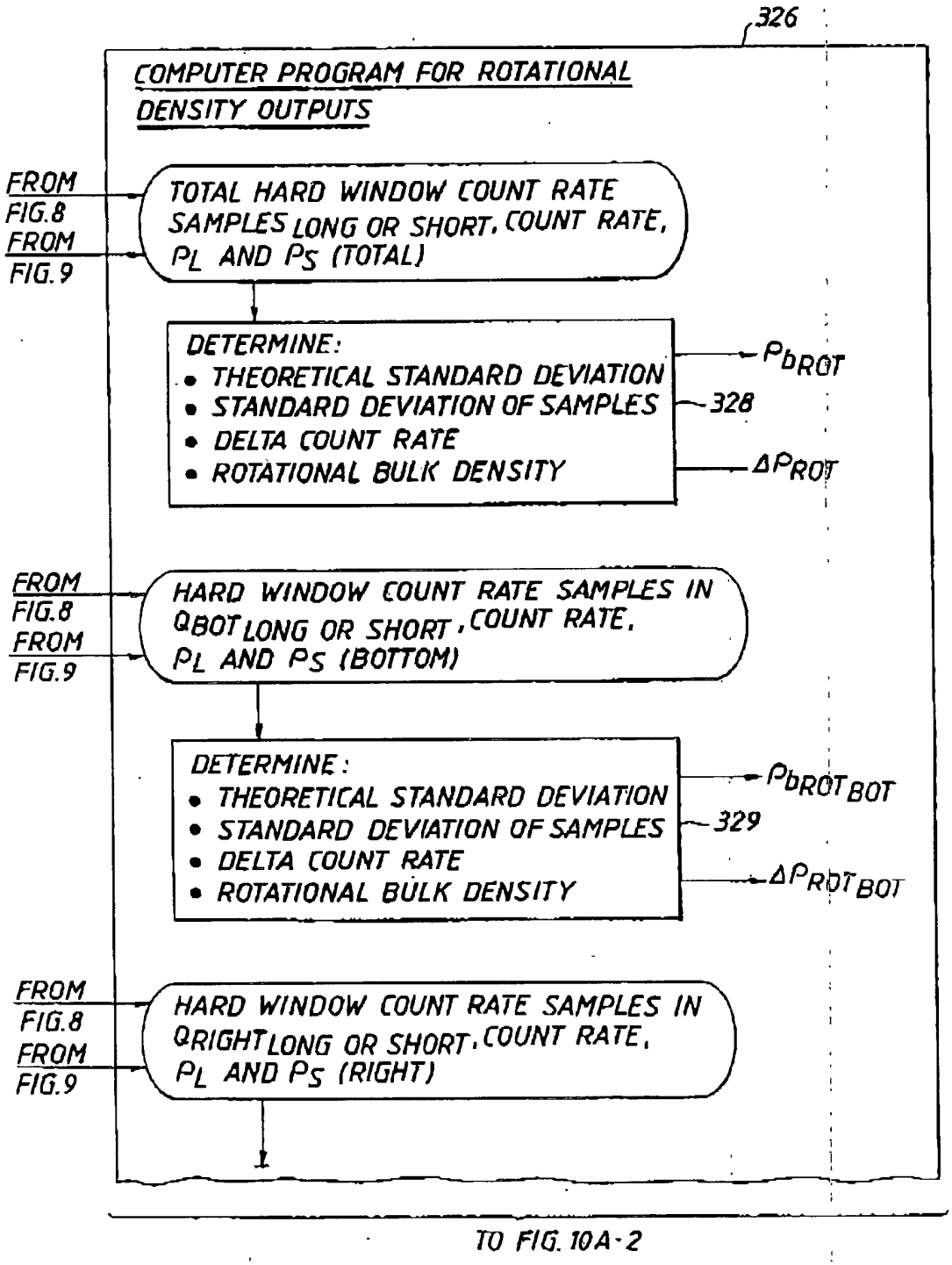
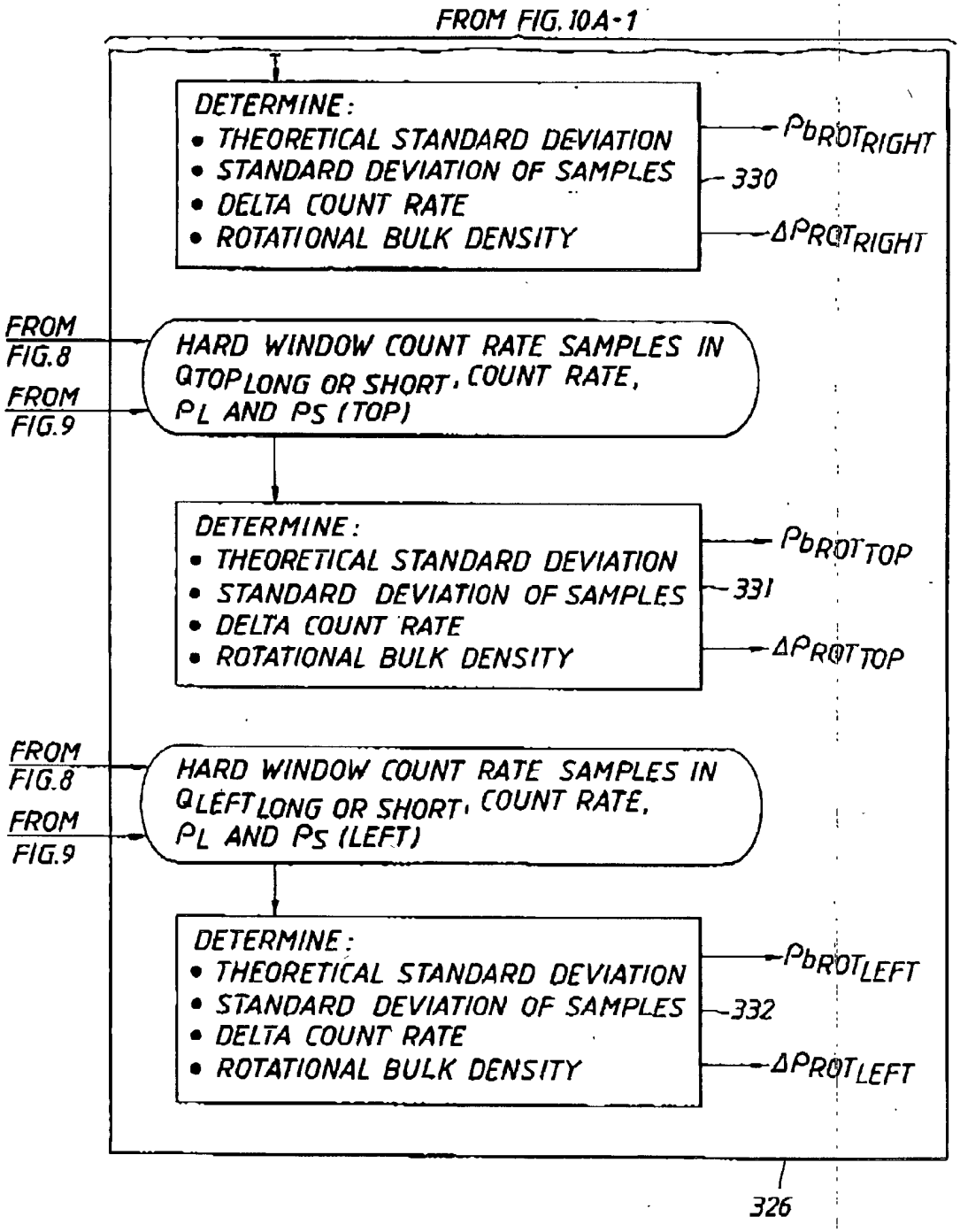

320
COMPUTER PROGRAM FOR BULK DENSITY OUTPUTS
FROM FIG.8
TOTAL HARD WINDOW COUNT RATE LONG
TOTAL HARD WINDOW COUNT RATE SHORT
321
SPINE & RIBS
PAVG : BULK DENSITY ENTIRE BOREHOLE
ΔP CORRECTION
PL, PS (TOTAL)
HARD WINDOW COUNT RATE IN QBOT LONG
HARD WINDOW COUNT RATE IN QBOT SHORT
322
SPINE & RIBS
BULK DENSITY BOTTOM Q (PAVG BOT)
ΔP CORRECTION
PL, PS (BOTTOM)
HARD WINDOW COUNT RATE IN QRIGHT LONG
HARD WINDOW COUNT RATE IN QRIGHT SHORT
323
SPINE & RIBS
BULK DENSITY RIGHT Q (PAVG RIGHT)
ΔP CORRECTION
PL, PS (RIGHT)
HARD WINDOW COUNT RATE IN QTOP LONG
HARD WINDOW COUNT RATE IN QTOP SHORT
324
SPINE & RIBS
BULK DENSITY TOP Q (PAVG TOP)
ΔP CORRECTION
PL, PS (TOP)
HARD WINDOW COUNT RATE IN QLEFT LONG
HARD WINDOW COUNT RATE IN QLEFT SHORT
325
SPINE & RIBS
BULK DENSITY LEFT Q (PAVG LEFT)
ΔP CORRECTION
PL, PS (LEFT)

FIG. 10A-1



TO FIG. 10A-2

FIG. 10A-2


FROM FIG. 10A-1
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
330
$P_{bROT_{RIGHT}}$
$\Delta P_{ROT_{RIGHT}}$
FROM FIG.8
FROM FIG.9
HARD WINDOW COUNT RATE SAMPLES IN $Q_{TOP_{LONG\ OR\ SHORT}}$, COUNT RATE, P_L AND P_S (TOP)
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
331
$P_{bROT_{TOP}}$
$\Delta P_{ROT_{TOP}}$
FROM FIG.8
FROM FIG.9
HARD WINDOW COUNT RATE SAMPLES IN $Q_{LEFT_{LONG\ OR\ SHORT}}$, COUNT RATE, P_L AND P_S (LEFT)
DETERMINE:
• THEORETICAL STANDARD DEVIATION
• STANDARD DEVIATION OF SAMPLES
• DELTA COUNT RATE
• ROTATIONAL BULK DENSITY
332
$P_{bROT_{LEFT}}$
$\Delta P_{ROT_{LEFT}}$
326

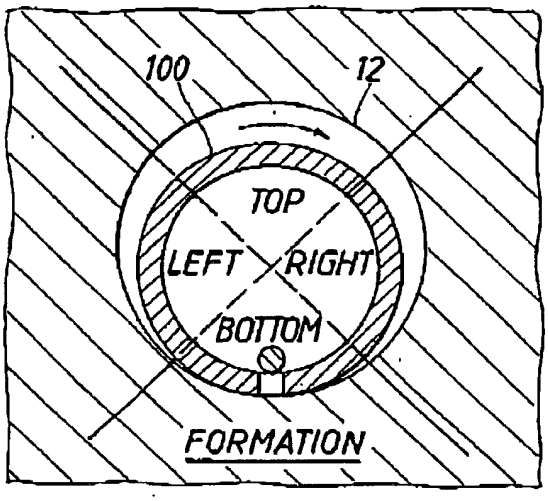


FIG.10B

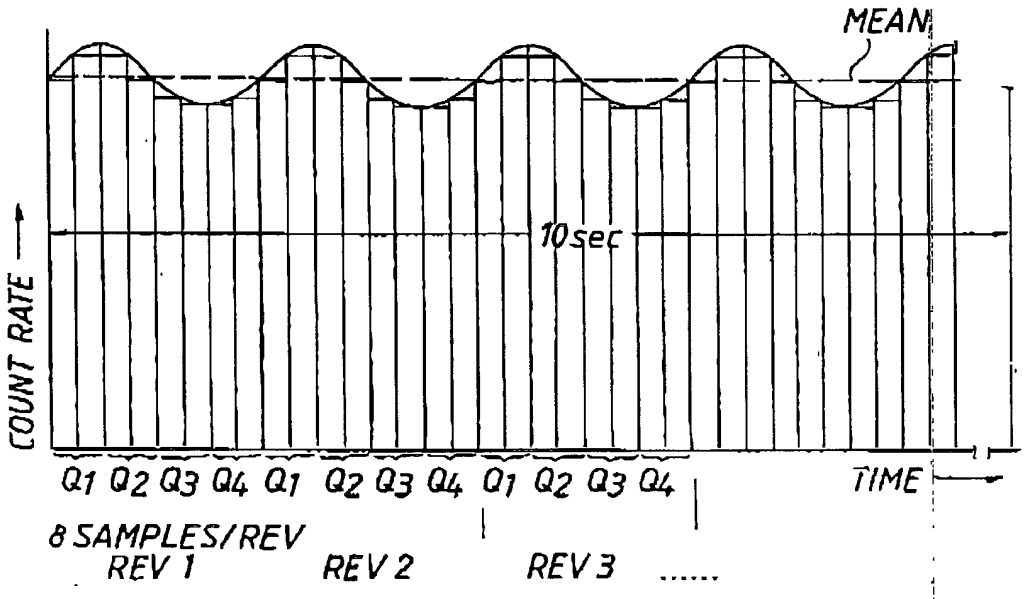
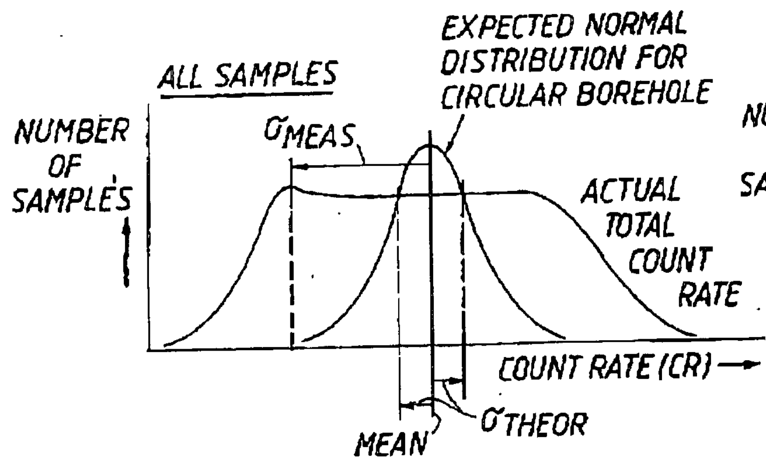


FIG.10C



$$\Delta CR = A\sqrt{\sigma^2_{MEAS} - \sigma^2_{THEOR}}$$

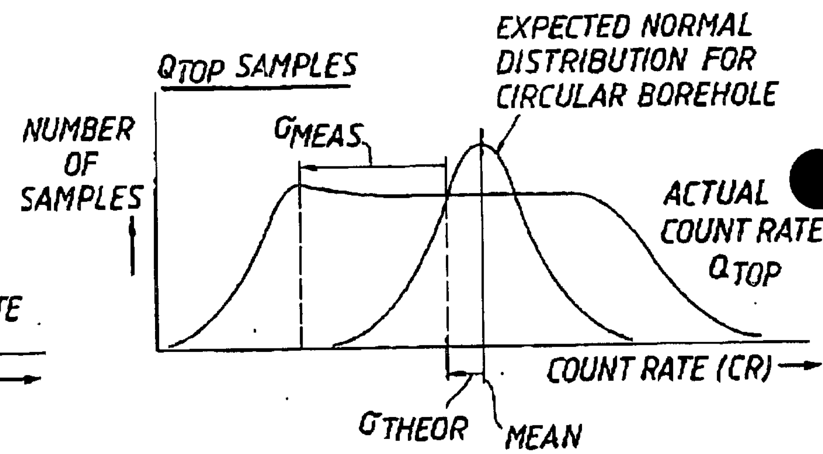
$$\Delta\rho_{ROT} = (ds)\left[\ln\left(\frac{CR+\Delta CR}{CR-\Delta CR}\right)\right]$$

$$\rho_{bROT} = D\rho_L + E\rho_S + F\Delta\rho_{ROT}$$

ρ_L = LONG SPACING DENSITY

ρ_S = SHORT SPACING DENSITY

FIG.10D-1



$$\Delta CR_{TOP} = A\sqrt{\sigma^2_{MEAS_{TOP}} - \sigma^2_{THEOR_{TOP}}}$$

$$\Delta\rho_{ROT_{TOP}} = (ds)\left[\ln\left(\frac{CR_{TOP} + \Delta CR_{TOP}}{CR_{TOP} - \Delta CR_{TOP}}\right)\right]$$

$$\rho_{bROT_{TOP}} = D\rho_{L_{TOP}} + E\rho_{S_{TOP}} + F\Delta\rho_{ROT_{TOP}}$$

$\rho_{L_{TOP}}$ = LONG SPACING DENSITY $_{TOP}$

$\rho_{S_{TOP}}$ = SHORT SPACING DENSITY $_{TOP}$

FIG.10D-2

FIG.11A

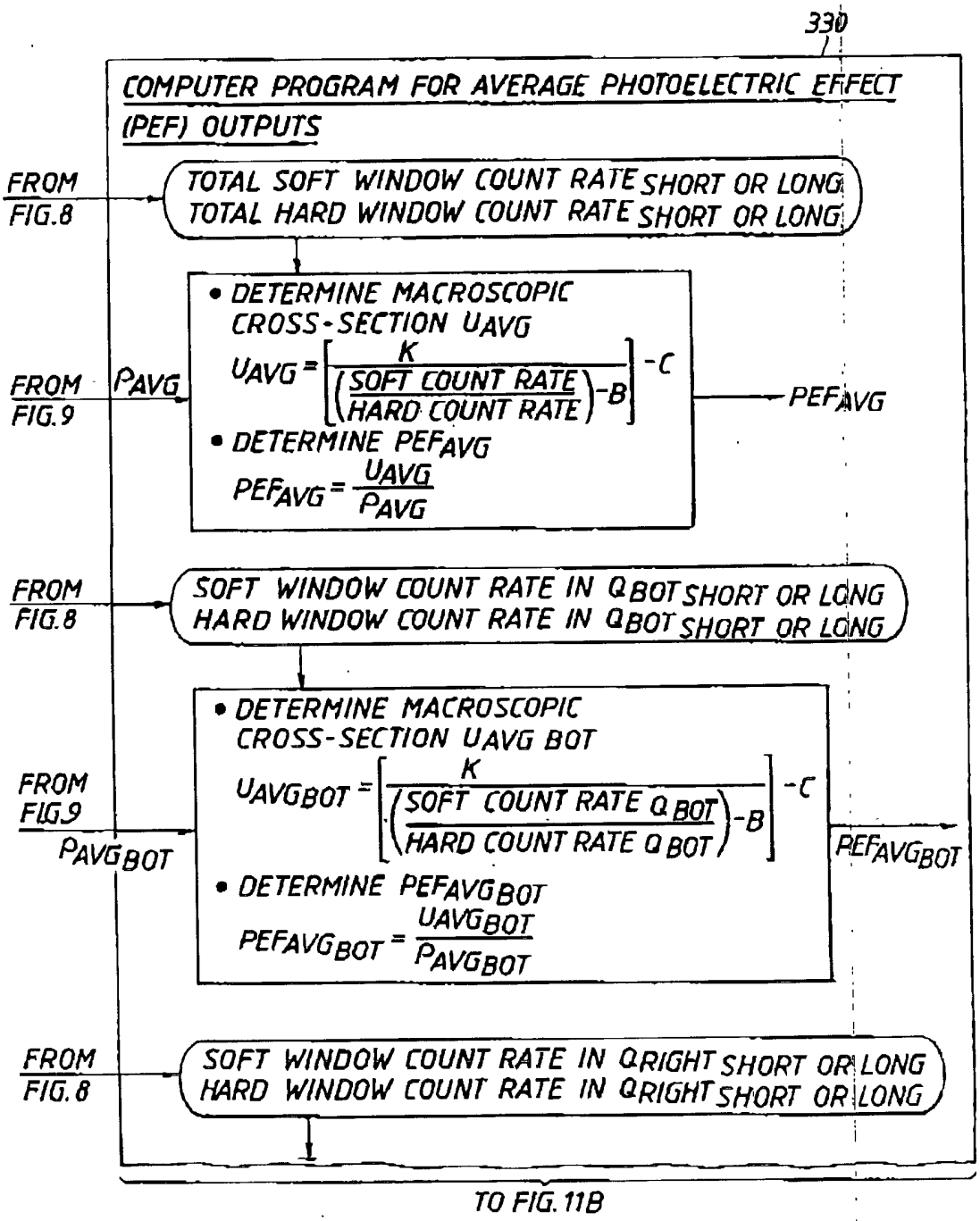

330
COMPUTER PROGRAM FOR AVERAGE PHOTOELECTRIC EFFECT (PEF) OUTPUTS
FROM FIG.8
TOTAL SOFT WINDOW COUNT RATE SHORT OR LONG
TOTAL HARD WINDOW COUNT RATE SHORT OR LONG
• DETERMINE MACROSCOPIC CROSS-SECTION UAVG
$U_{AVG} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$
FROM FIG.9
ρ_{AVG}
• DETERMINE PEF_{AVG}
$PEF_{AVG} = \frac{U_{AVG}}{\rho_{AVG}}$
PEF_{AVG}
FROM FIG.8
SOFT WINDOW COUNT RATE IN Q_{BOT} SHORT OR LONG
HARD WINDOW COUNT RATE IN Q_{BOT} SHORT OR LONG
• DETERMINE MACROSCOPIC CROSS-SECTION $U_{AVG\ BOT}$
$U_{AVG_{BOT}} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE } Q_{BOT}}{\text{HARD COUNT RATE } Q_{BOT}}\right) - B}\right] - C$
FROM FIG.9
$\rho_{AVG_{BOT}}$
• DETERMINE $PEF_{AVG_{BOT}}$
$PEF_{AVG_{BOT}} = \frac{U_{AVG_{BOT}}}{\rho_{AVG_{BOT}}}$
$PEF_{AVG_{BOT}}$
FROM FIG.8
SOFT WINDOW COUNT RATE IN Q_{RIGHT} SHORT OR LONG
HARD WINDOW COUNT RATE IN Q_{RIGHT} SHORT OR LONG
TO FIG.11B

FIG. 11B

FROM FIG. 11A

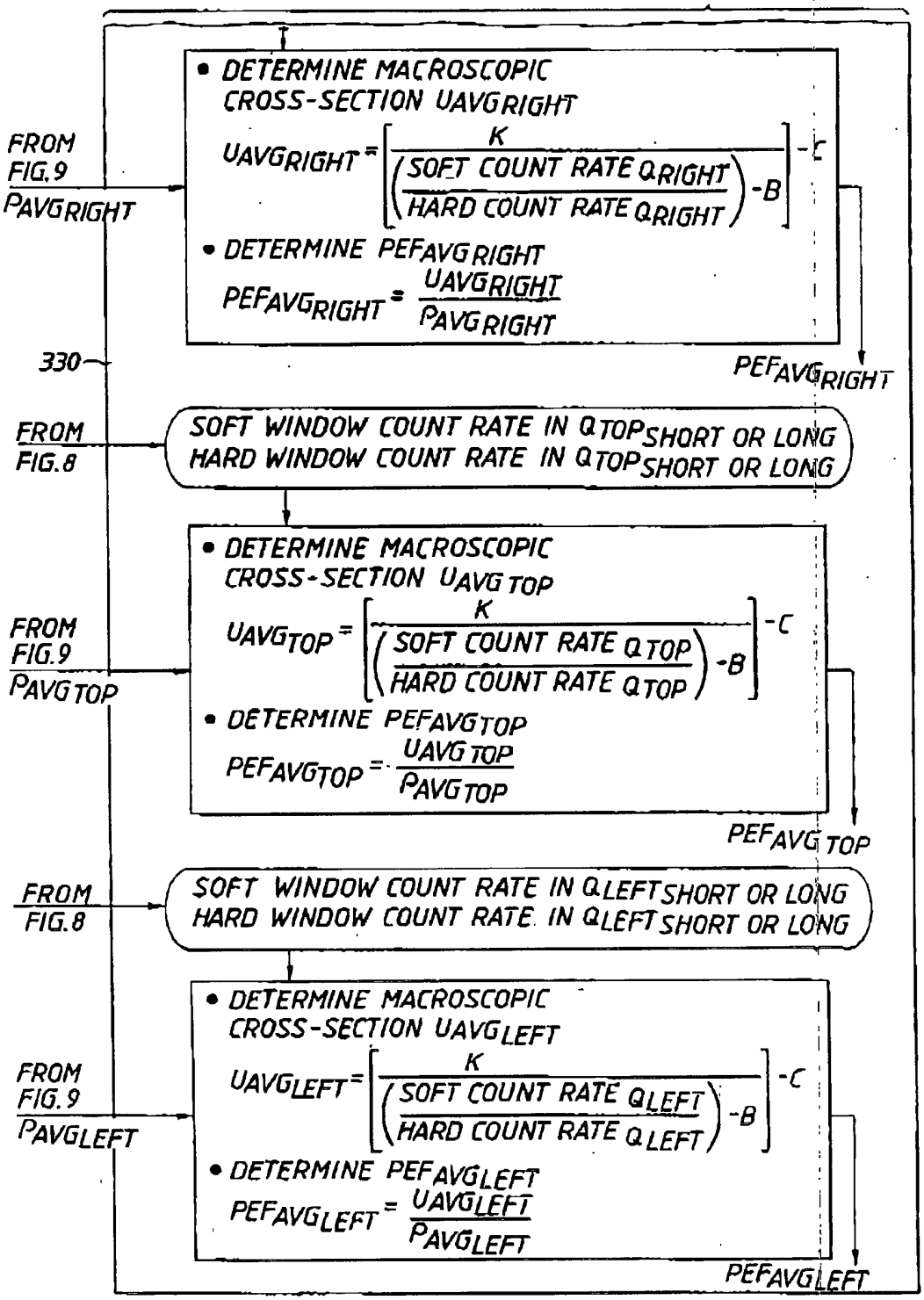


FIG. 12A

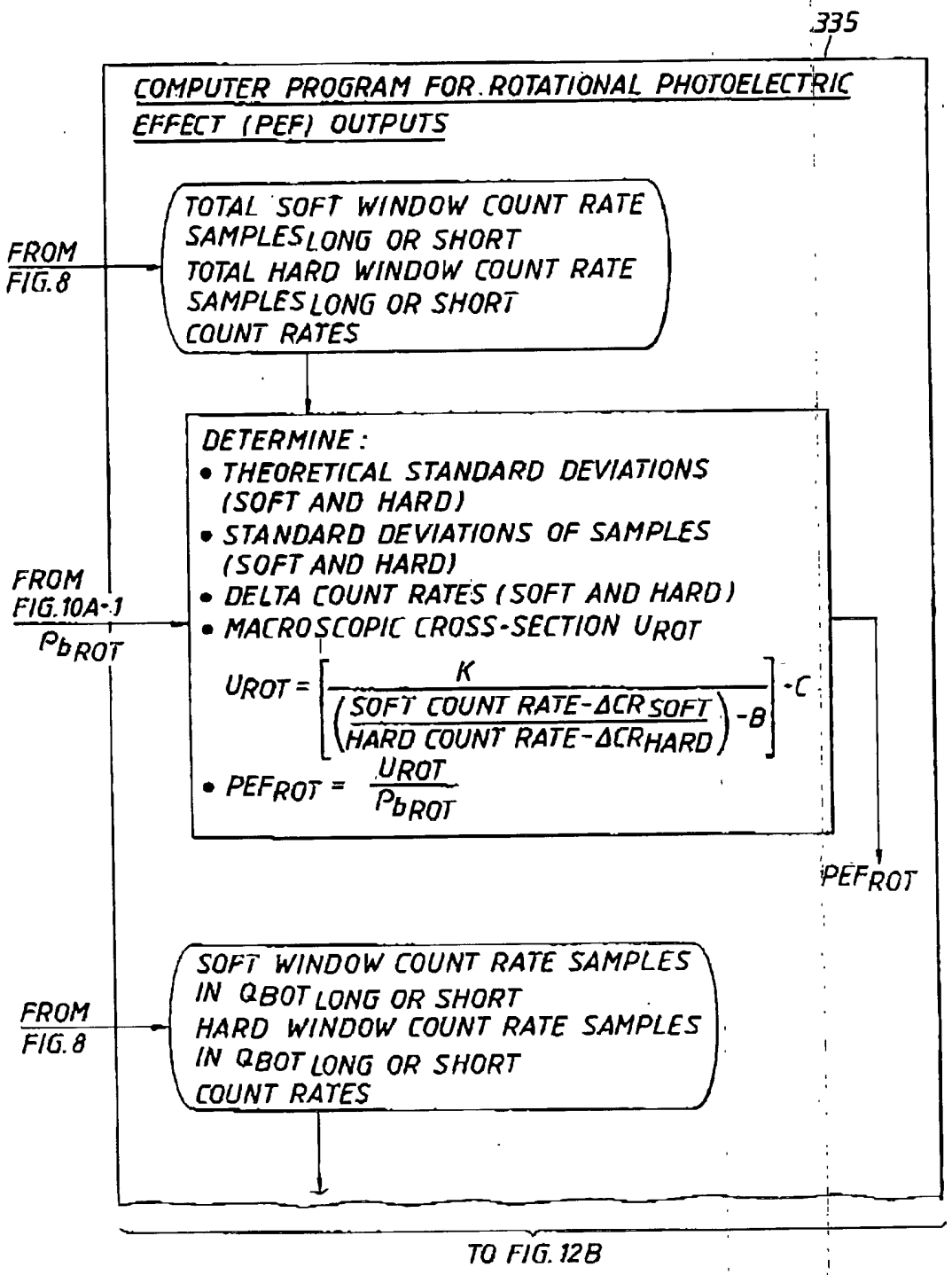

335
COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC EFFECT (PEF) OUTPUTS
FROM FIG. 8
TOTAL SOFT WINDOW COUNT RATE SAMPLES LONG OR SHORT
TOTAL HARD WINDOW COUNT RATE SAMPLES LONG OR SHORT
COUNT RATES
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION U_{ROT}
$U_{ROT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}}\right) - B}\right] - C$
• $PEF_{ROT} = \frac{U_{ROT}}{P_{bROT}}$
FROM FIG. 10A-1
P_{bROT}
PEF_{ROT}
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN Q_{BOT} LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN Q_{BOT} LONG OR SHORT
COUNT RATES
TO FIG. 12B

FIG. 12B

FROM FIG. 12A

DETERMINE:
- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION $UROT_{BOT}$

FROM FIG. 10A-1 $PbROT_{BOT}$

$$UROT_{BOT} = \left[\frac{K}{\left(\frac{SOFT\ COUNT\ RATE - \Delta CR_{SOFT}}{HARD\ COUNT\ RATE - \Delta CR_{HARD}}\right) - B}\right] - C$$

335

- $PEFROT_{BOT} = \frac{UROT_{BOT}}{PbROT_{BOT}}$

$PEFROT_{BOT}$

FROM FIG. 8: SOFT WINDOW COUNT RATE SAMPLES IN $Q_{RIGHT\ LONG\ OR\ SHORT}$ HARD WINDOW COUNT RATE SAMPLES IN $Q_{RIGHT\ LONG\ OR\ SHORT}$ COUNT RATES

DETERMINE:
- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION $UROT_{RIGHT}$

FROM FIG. 10A-2 $PbROT_{RIGHT}$

$$UROT_{RIGHT} = \left[\frac{K}{\left(\frac{SOFT\ COUNT\ RATE - \Delta CR_{SOFT}}{HARD\ COUNT\ RATE - \Delta CR_{HARD}}\right) - B}\right] - C$$

- $PEFROT_{RIGHT} = \frac{UROT_{RIGHT}}{PbROT_{RIGHT}}$

$PEFROT_{RIGHT}$

FROM FIG. 8: SOFT WINDOW COUNT RATE SAMPLES IN $Q_{TOP\ LONG\ OR\ SHORT}$ HARD WINDOW COUNT RATE SAMPLES IN $Q_{TOP\ LONG\ OR\ SHORT}$ COUNT RATES

TO FIG. 12C

FIG. 12

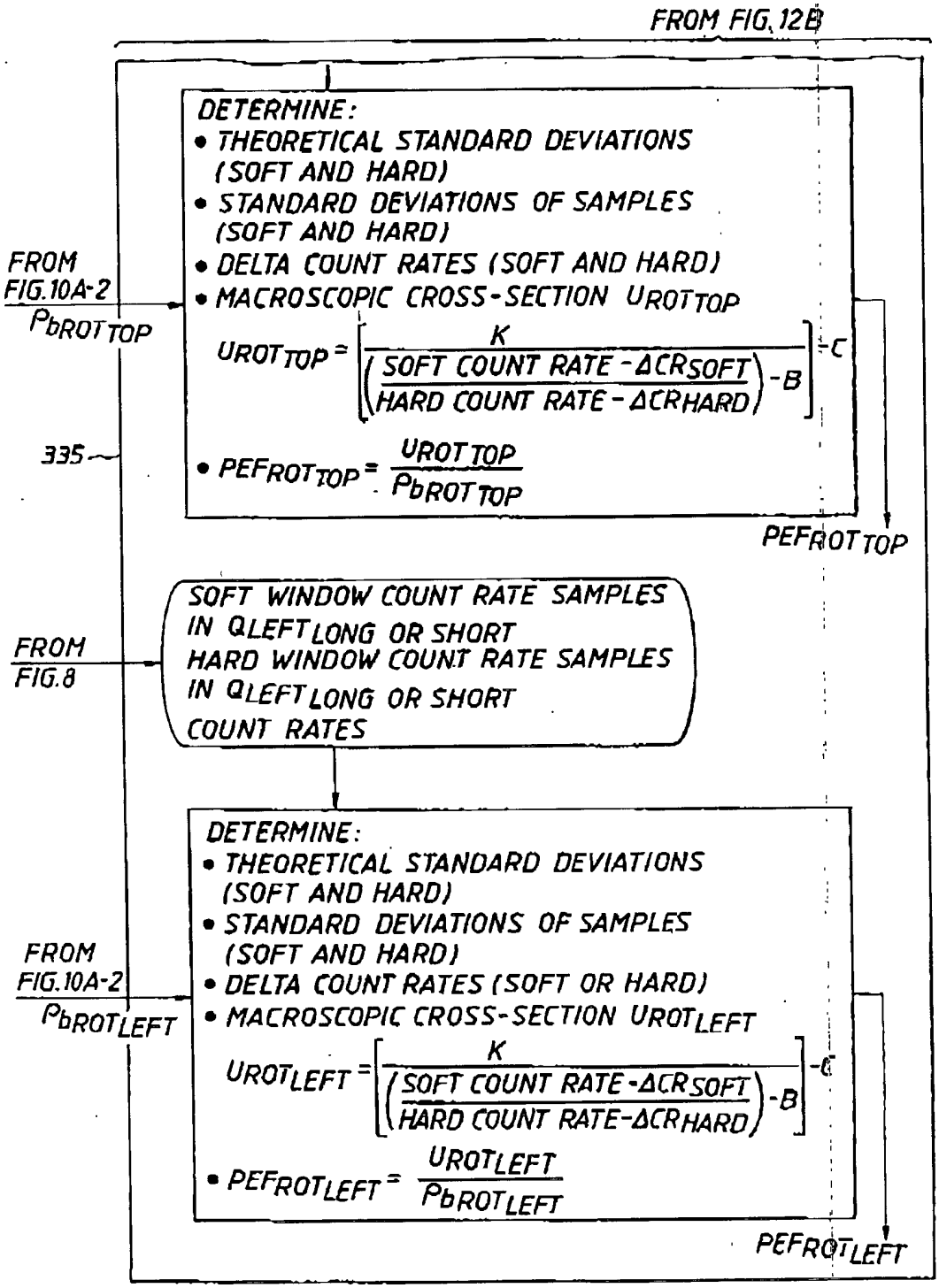

FROM FIG. 12B
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT AND HARD)
• MACROSCOPIC CROSS-SECTION UROTTOP
UROTTOP = [K / ((SOFT COUNT RATE - ΔCRSOFT) / (HARD COUNT RATE - ΔCRHARD) - B)] - C
335
• PEFROTTOP = UROTTOP / PbROTTOP
FROM FIG. 10A-2
PbROTTOP
PEFROTTOP
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN QLEFTLONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN QLEFTLONG OR SHORT
COUNT RATES
DETERMINE:
• THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
• STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
• DELTA COUNT RATES (SOFT OR HARD)
• MACROSCOPIC CROSS-SECTION UROTLEFT
UROTLEFT = [K / ((SOFT COUNT RATE - ΔCRSOFT) / (HARD COUNT RATE - ΔCRHARD) - B)] - C
• PEFROTLEFT = UROTLEFT / PbROTLEFT
FROM FIG. 10A-2
PbROTLEFT
PEFROTLEFT

FIG. 12D

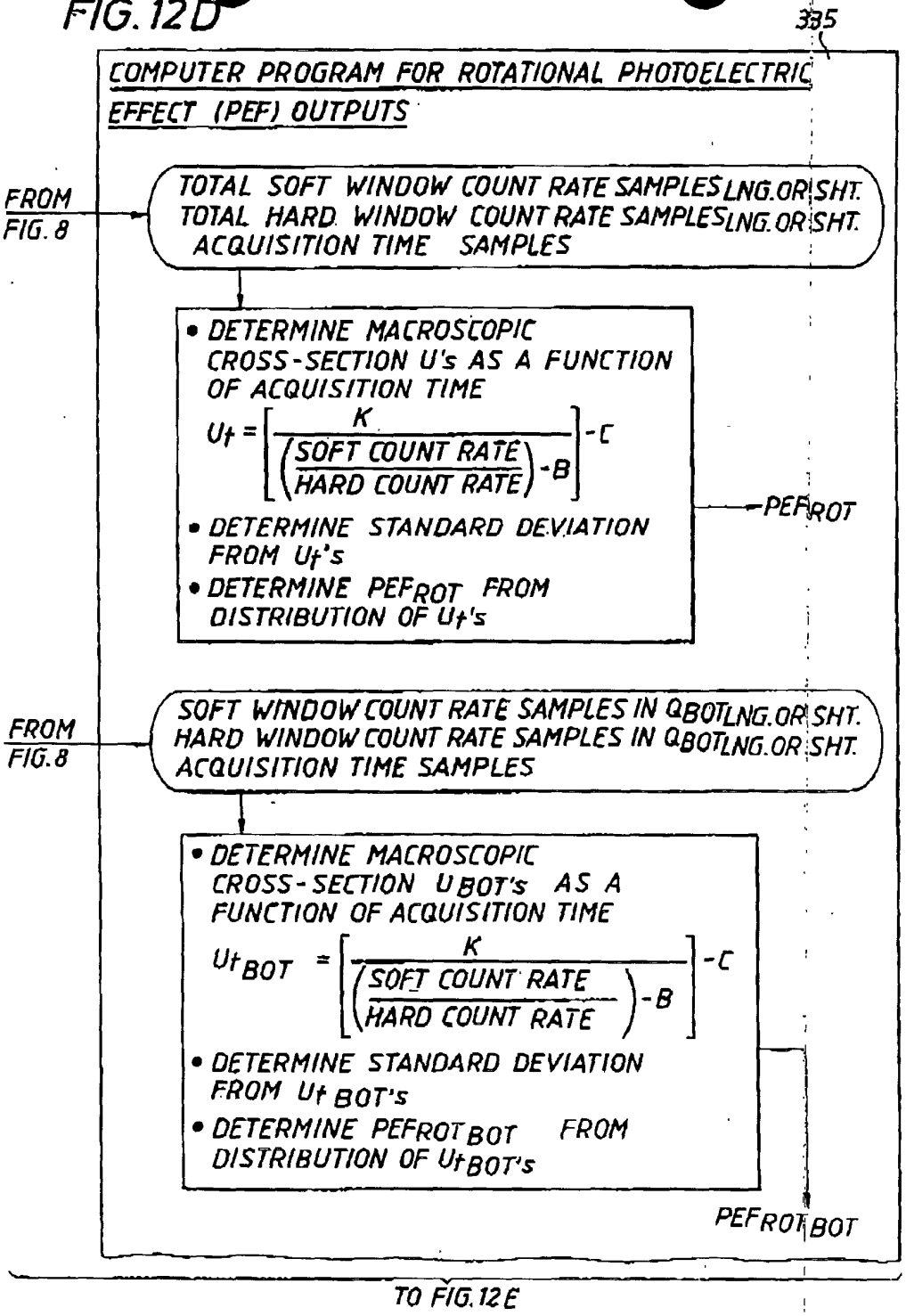

335
COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC EFFECT (PEF) OUTPUTS
FROM FIG. 8
TOTAL SOFT WINDOW COUNT RATE SAMPLES LNG. OR SHT.
TOTAL HARD WINDOW COUNT RATE SAMPLES LNG. OR SHT.
ACQUISITION TIME SAMPLES
• DETERMINE MACROSCOPIC CROSS-SECTION U's AS A FUNCTION OF ACQUISITION TIME
$U_f = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$
• DETERMINE STANDARD DEVIATION FROM U_f's
• DETERMINE PEF_{ROT} FROM DISTRIBUTION OF U_f's
PEF_{ROT}
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN Q_{BOT} LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN Q_{BOT} LNG. OR SHT.
ACQUISITION TIME SAMPLES
• DETERMINE MACROSCOPIC CROSS-SECTION U_{BOT}'s AS A FUNCTION OF ACQUISITION TIME
$U_{f_{BOT}} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$
• DETERMINE STANDARD DEVIATION FROM $U_{f\,BOT}$'s
• DETERMINE $PEF_{ROT\,BOT}$ FROM DISTRIBUTION OF $U_{f\,BOT}$'s
$PEF_{ROT\,BOT}$
TO FIG. 12E

FIG. 12E

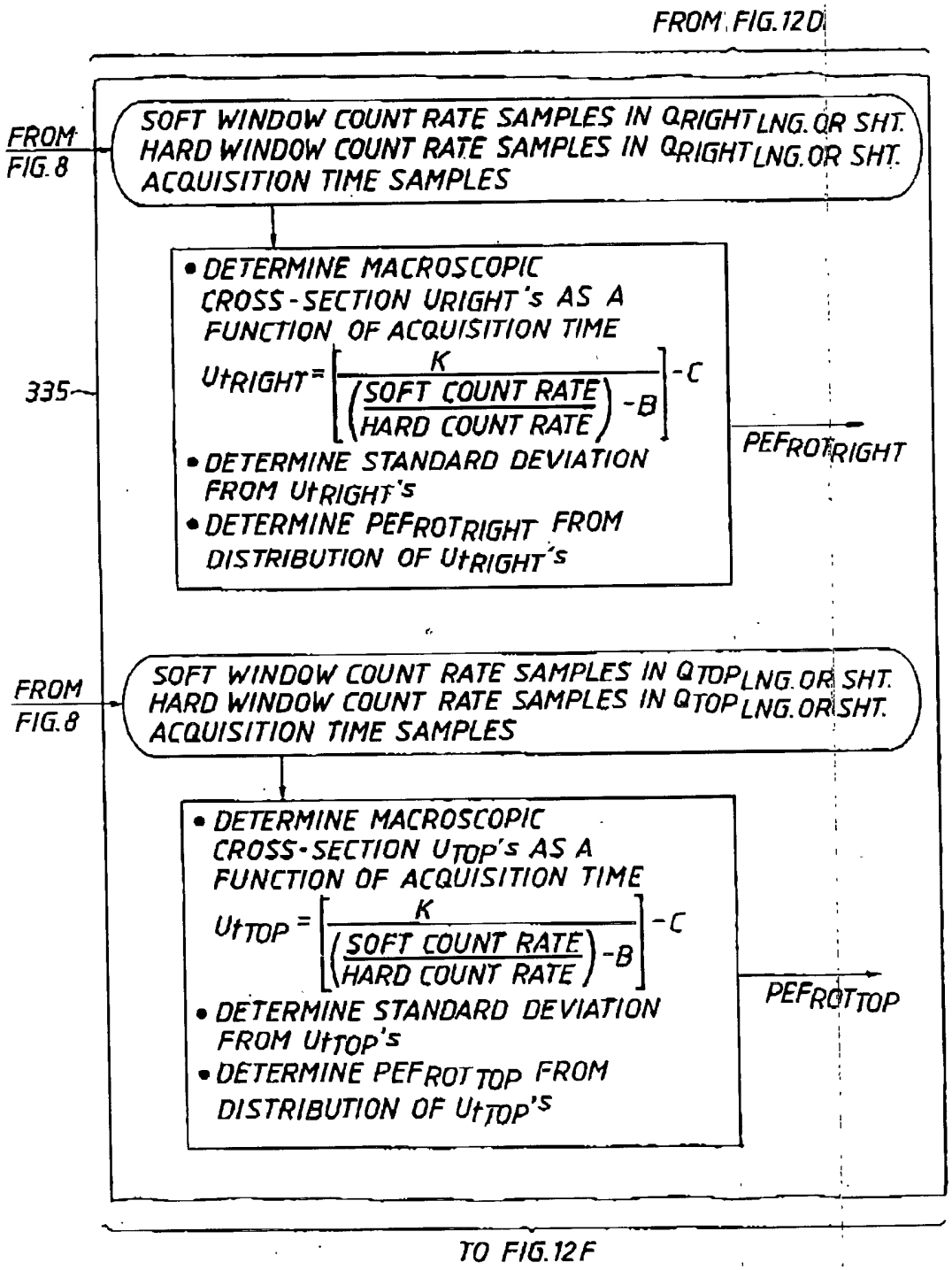

FROM FIG. 12D
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.
ACQUISITION TIME SAMPLES
335
• DETERMINE MACROSCOPIC CROSS-SECTION URIGHT's AS A FUNCTION OF ACQUISITION TIME
UtRIGHT = [K / ((SOFT COUNT RATE / HARD COUNT RATE) - B)] - C
• DETERMINE STANDARD DEVIATION FROM UtRIGHT's
• DETERMINE PEFROTRIGHT FROM DISTRIBUTION OF UtRIGHT's
PEFROTRIGHT
FROM FIG. 8
SOFT WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.
ACQUISITION TIME SAMPLES
• DETERMINE MACROSCOPIC CROSS-SECTION UTOP's AS A FUNCTION OF ACQUISITION TIME
UtTOP = [K / ((SOFT COUNT RATE / HARD COUNT RATE) - B)] - C
• DETERMINE STANDARD DEVIATION FROM UtTOP's
• DETERMINE PEFROTTOP FROM DISTRIBUTION OF UtTOP's
PEFROTTOP
TO FIG. 12F

FIG. 12F

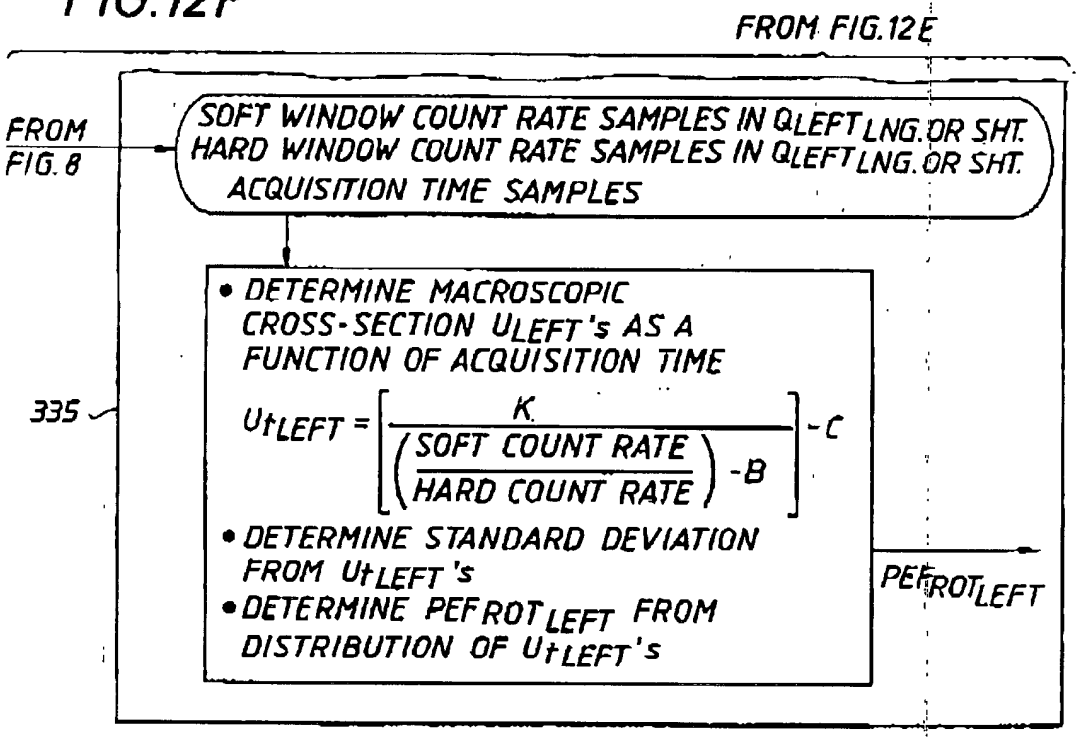


FIG. 13

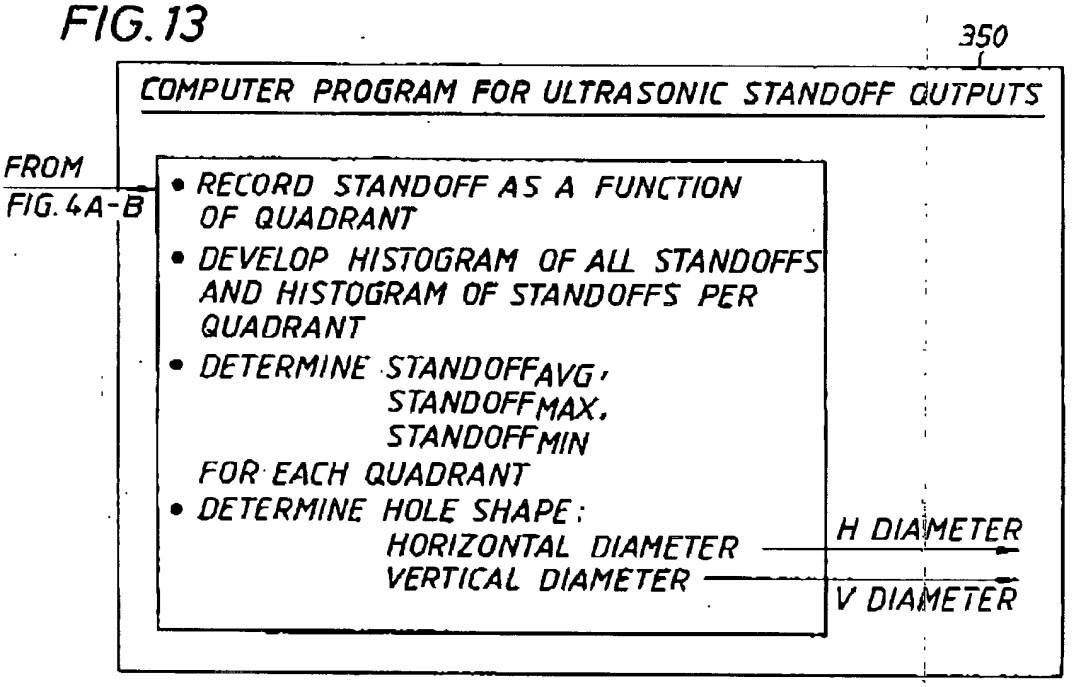


FIG. 14A

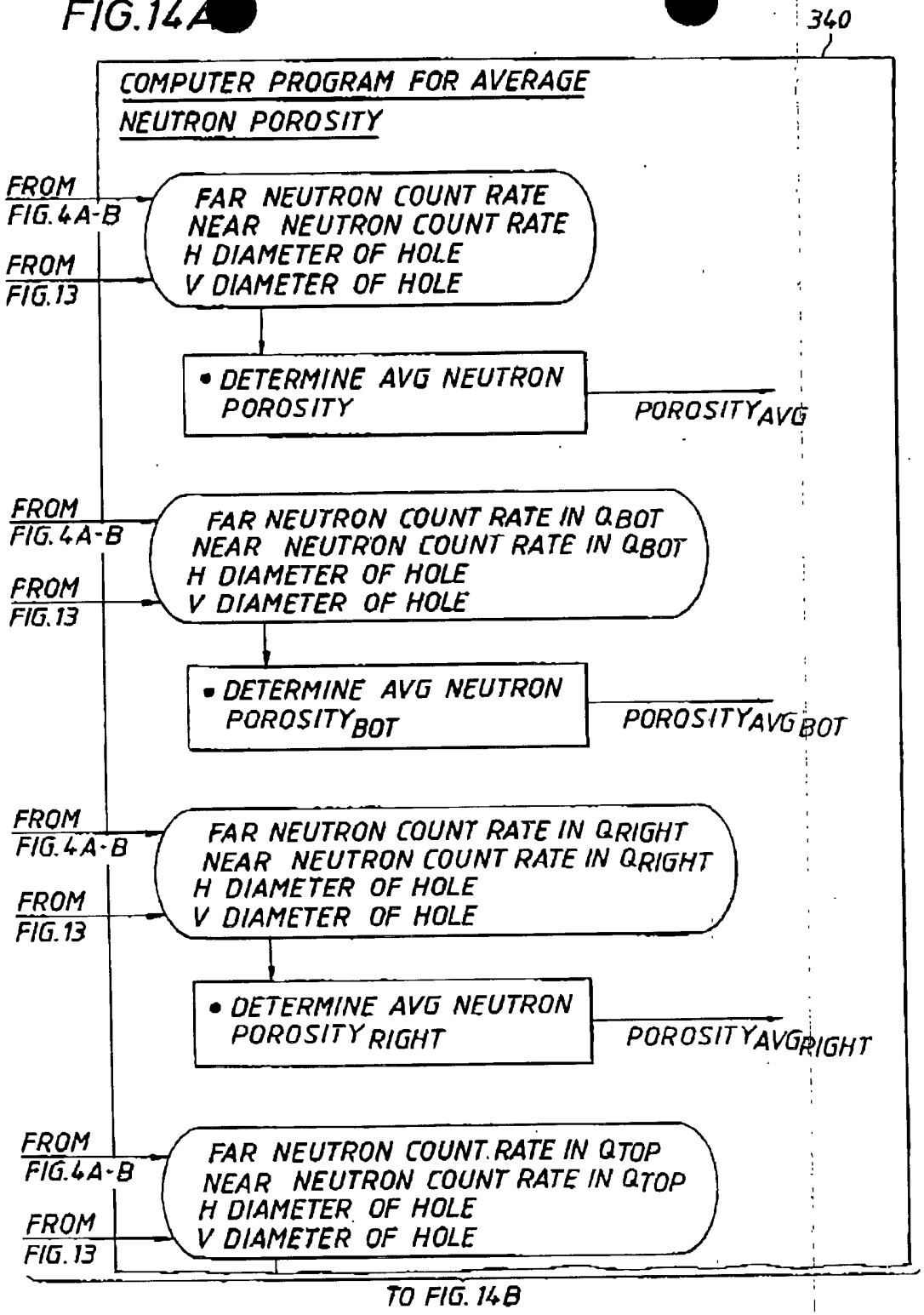

340
COMPUTER PROGRAM FOR AVERAGE NEUTRON POROSITY
FROM FIG. 4A-B
FAR NEUTRON COUNT RATE
NEAR NEUTRON COUNT RATE
FROM FIG. 13
H DIAMETER OF HOLE
V DIAMETER OF HOLE
• DETERMINE AVG NEUTRON POROSITY
POROSITY AVG
FROM FIG. 4A-B
FAR NEUTRON COUNT RATE IN Q BOT
NEAR NEUTRON COUNT RATE IN Q BOT
FROM FIG. 13
H DIAMETER OF HOLE
V DIAMETER OF HOLE
• DETERMINE AVG NEUTRON POROSITY BOT
POROSITY AVG BOT
FROM FIG. 4A-B
FAR NEUTRON COUNT RATE IN Q RIGHT
NEAR NEUTRON COUNT RATE IN Q RIGHT
FROM FIG. 13
H DIAMETER OF HOLE
V DIAMETER OF HOLE
• DETERMINE AVG NEUTRON POROSITY RIGHT
POROSITY AVG RIGHT
FROM FIG. 4A-B
FAR NEUTRON COUNT RATE IN Q TOP
NEAR NEUTRON COUNT RATE IN Q TOP
FROM FIG. 13
H DIAMETER OF HOLE
V DIAMETER OF HOLE
TO FIG. 14B

FIG. 14B

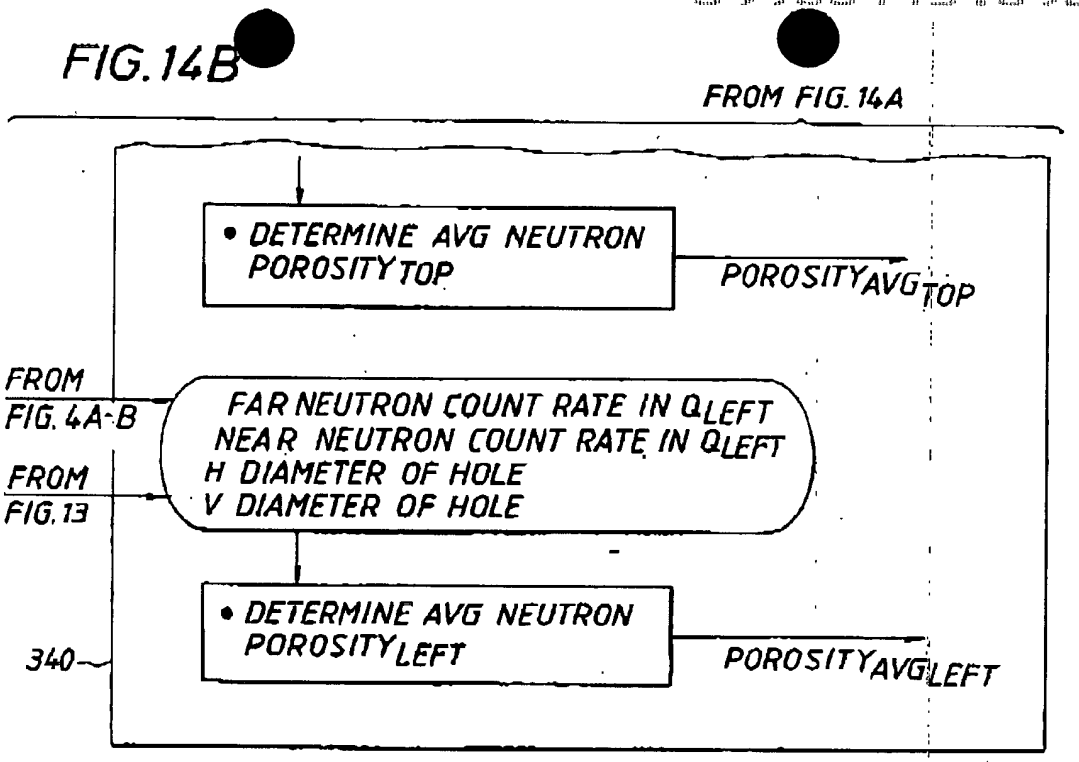


FIG. 15A

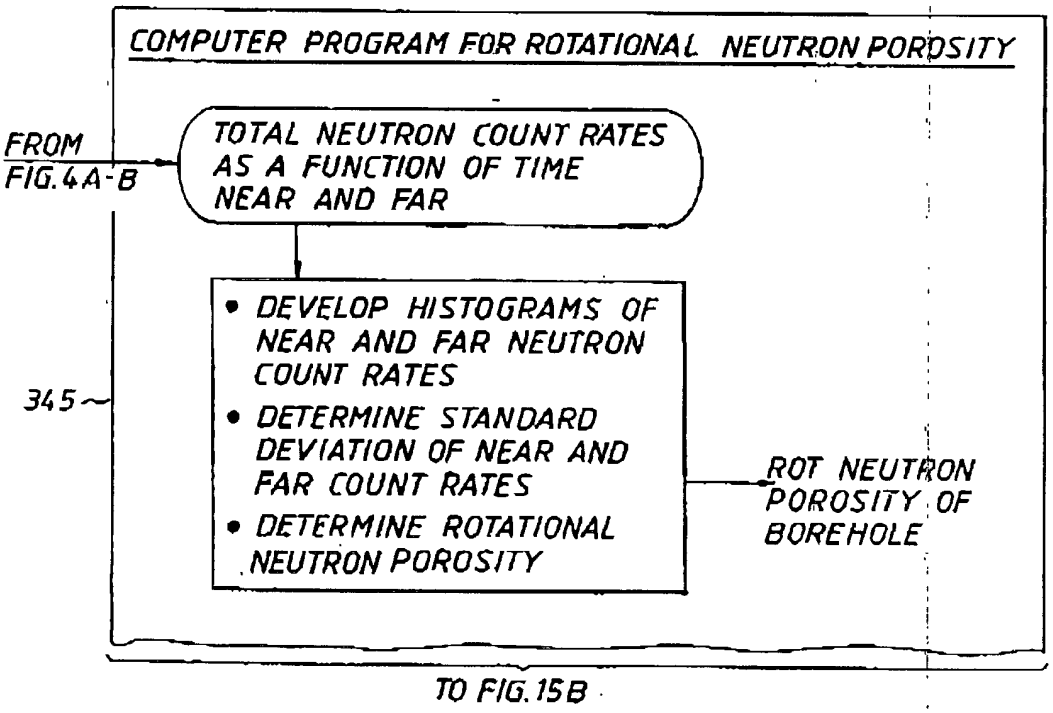


FIG. 15B

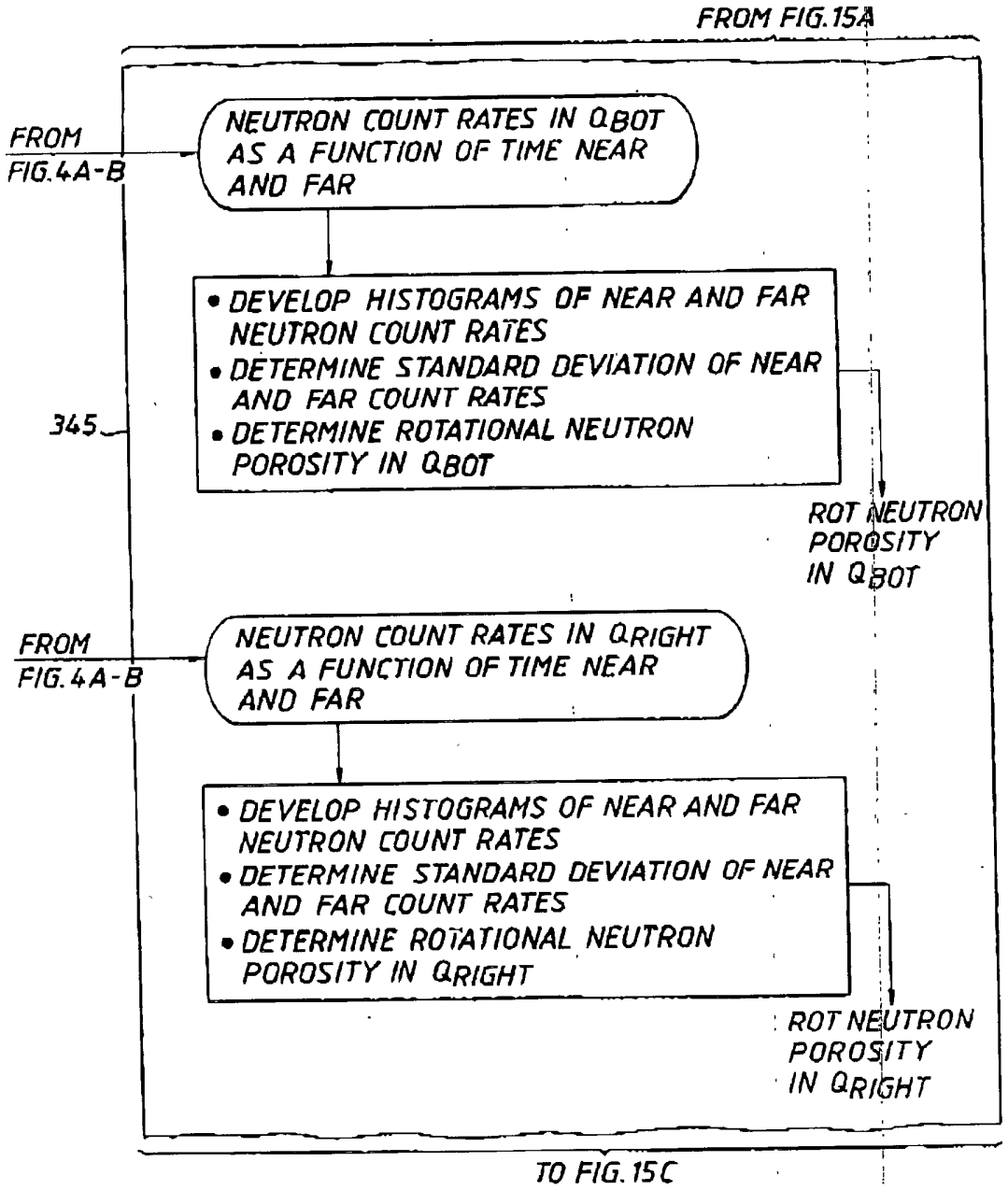
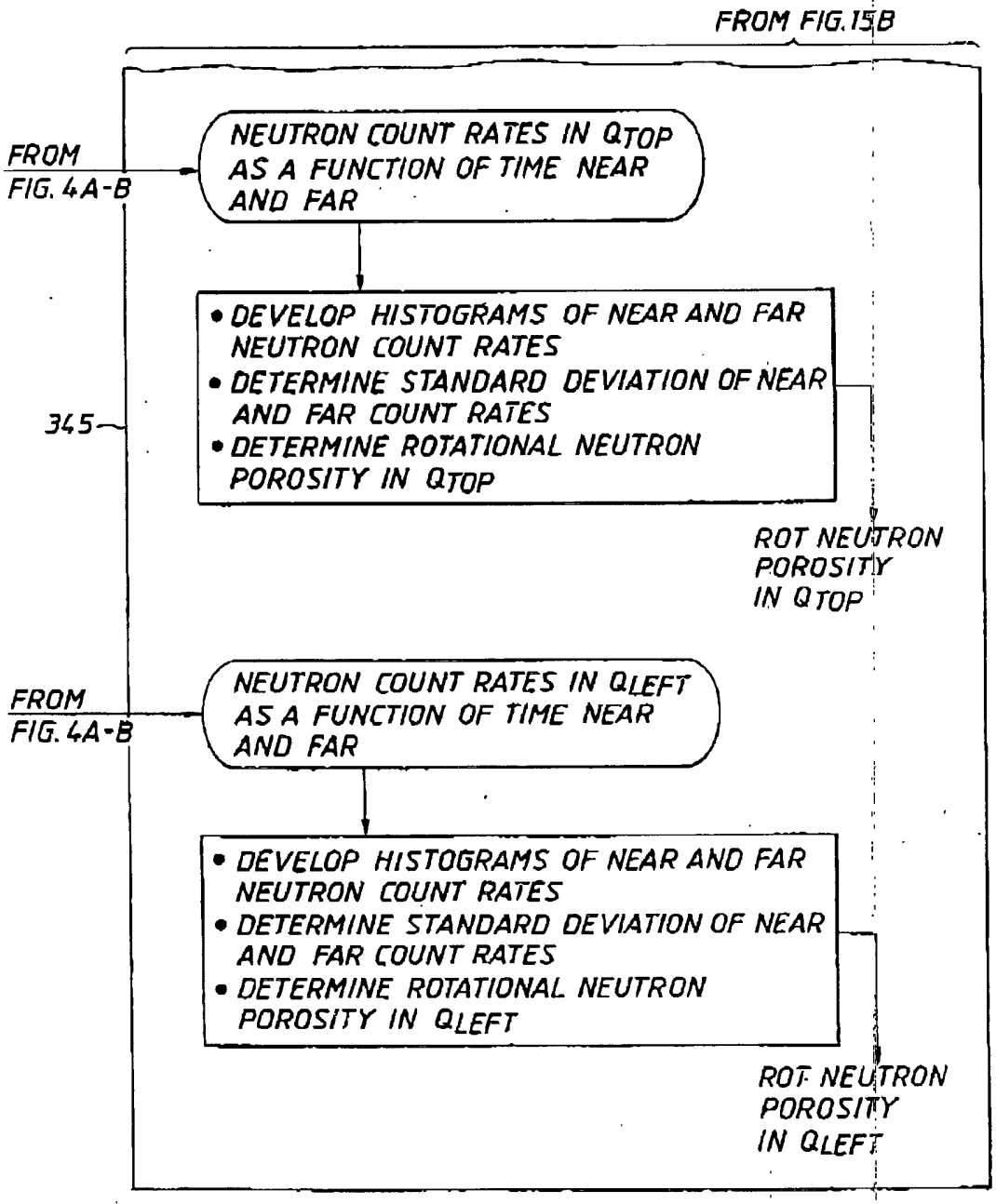

FROM FIG. 15A
FROM FIG. 4A-B
NEUTRON COUNT RATES IN QBOT AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QBOT
345
ROT NEUTRON POROSITY IN QBOT
FROM FIG. 4A-B
NEUTRON COUNT RATES IN QRIGHT AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QRIGHT
ROT NEUTRON POROSITY IN QRIGHT
TO FIG. 15C

FIG. 15C


FROM FIG. 15B
FROM FIG. 4A-B
NEUTRON COUNT RATES IN QTOP AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QTOP
345
ROT NEUTRON POROSITY IN QTOP
FROM FIG. 4A-B
NEUTRON COUNT RATES IN QLEFT AS A FUNCTION OF TIME NEAR AND FAR
• DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
• DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
• DETERMINE ROTATIONAL NEUTRON POROSITY IN QLEFT
ROT NEUTRON POROSITY IN QLEFT

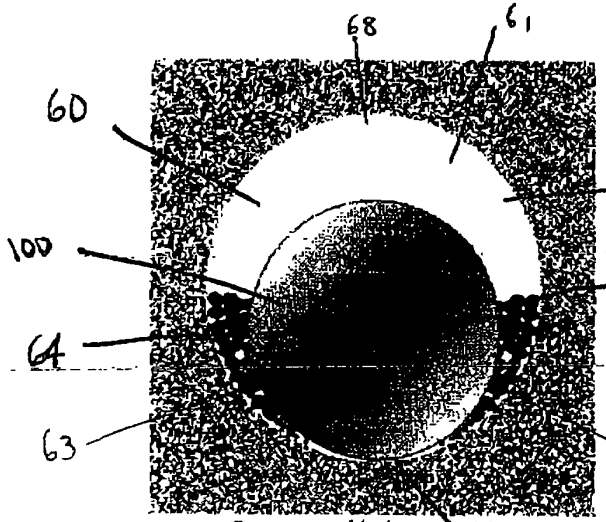


Figure 16A

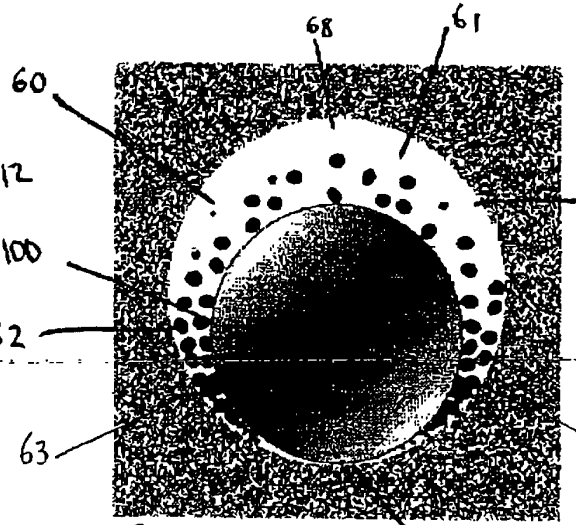


Figure 16B

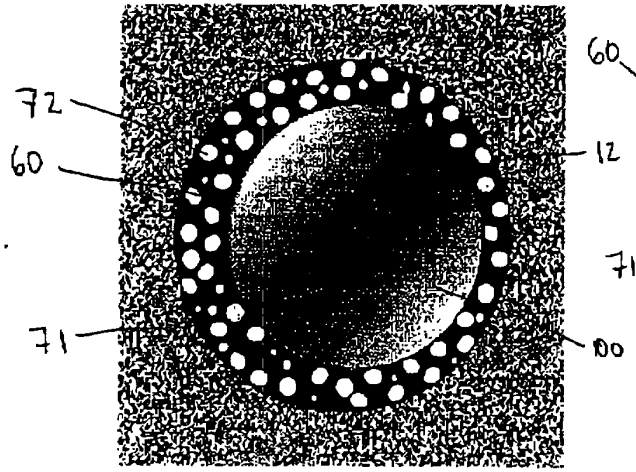


Figure 17A

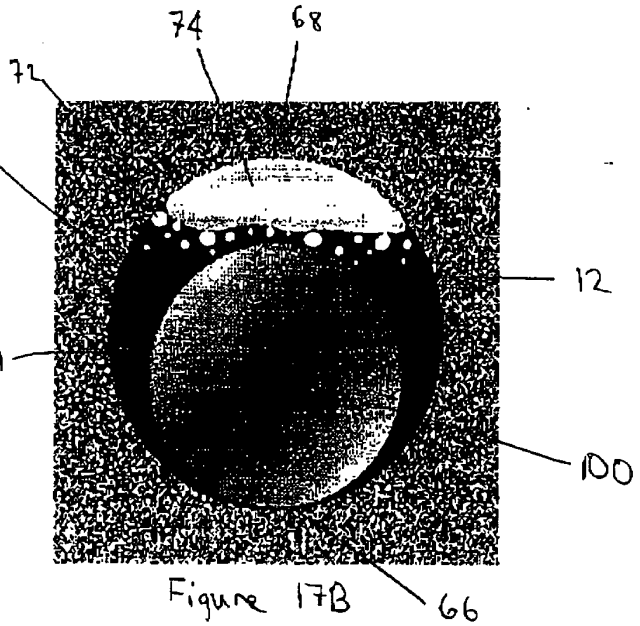


Figure 17B